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OUTLINE OF SCIENCE

PART I

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VOLUME III

OUTLINE OF SCIENCE

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PART I
MAN AND HIS ENVIRONMENT

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OUTLINE OF SCIENCE

PART I

I

THE UNIVERSE IN WHICH WE LIVE

Man Discovers the Solar System

ASTRONOMY is our oldest science. With little to do during the long dark evenings, it is not surprizing that thoughtful men should early have turned their attention to the study of the heavens. Particularly should this be expected when it is realized that the people of that early age were much more dependent upon the weather than are we to-day. All the bounties of nature proceeded from the heavens. The result was that altogether too much credit was given to the skies; they were even credited with control of all our destinies. Thus astrology grew up along with astronomy, and has only recently been shaken off.

The Chaldeans made a systematic study of astronomy as early as 4000 B. C., as evidenced by old records. They even predicted eclipses. The records show that the Chinese were able to

determine equinoxes and solstices as early as 1100 B. C. They had calculated the obliquity of the ecliptic and its diminution. The Greek philosophers from 600 B. C. to 300 B. C. taught that the stars shone from their own light, whereas the moon shone from reflected light. They even suggested that the earth was spherical and revolved around the sun. Hipparchus (150 B. C.) made a catalog of over a thousand stars, and divided them into six classes according to their brightness. With the decay of Greece, true astronomy slumbered until after the Renaissance. The new astronomy was born with Copernicus in 1500 A. D., and was carried forward by the observations of Tycho Brahe and the imagination and brilliance of Kepler, who gave us an exact statement of the motion of the planets and afforded a predicting power to astronomers which could not previously have been dreamed of.

Their work fell into the hands of able successors. Galileo invented the telescope, introduced the pendulum for the exact measurement of time, and recognized the true nature of motion and force. His experiments on falling bodies at the tower of Pisa constituted a greater step forward than had been taken for centuries previous, or, one might add, than has been taken since. Newton, about 1700, climaxed all that had gone before in the pronouncement of his universal law of gravitation. He pointed out, as it

were, what it was that made the wheels go around. This law reduced the motions of the heavenly bodies from an unfathomable mystery to a problem capable of exact calculation. The great mathematicians, Lagrange and Laplace, working on Newton's theory, demonstrated the mechanical stability of the solar system. This was a great confirmation of Newton's work. A greater came, however, in the work of Adams and La Verrier in the nineteenth century. Investigating the irregularities in the orbit of Uranus, they concluded that these could not be entirely due, as supposed, to Jupiter and Saturn. They were thus led to assert the existence of a hitherto undiscovered planet. They computed its exact orbit and its position in that orbit at the time. When telescopes examined the heavens for evidence of such a planet, it was found—an uncharted star of the eighth magnitude, not previously observed. It was the planet Neptune. A great triumph for the Newtonian theory!

Of late the astronomers have shifted their gaze from the solar system, the problems of which have been so thoroughly solved by such great minds as those mentioned above, and are investigating the nebulæ and the stars. We are now attempting to solve the problems of the universe. We want to know how stars and solar systems have their birth. We want to know the extent and the shape of the universe. Our modern

astronomers are doing admirable work. Our daily press is constantly announcing new achievements. The new vistas that are opened up to human thought are astounding. Astronomy today is influencing our lives as much as it did in the pre-Christian era.

Putting Stars in "Test Tubes"

The materials of which the sun and stars are made are the same as those found upon the earth. If we consider the sun, which in fact is our nearest star, we can say that as many as fifty-eight of the ninety-two known elements have been definitely identified in the sun's composition. Hence we may expect to find that the other stars are similarly composed, and while not so large a number have been found for these more distant heavenly bodies, they are doubtless there. It is quite unlikely that we shall ever be able to find all the known elements in the stars. Some, as is the case on our earth, may be present in quantities too small ever to make it a possible task.

In identifying these distant elements the method of spectroscopy is used. We recognize them by the light which they emit. Newton first placed a glass prism in front of a beam of sunlight and split it up into its component parts. This led to the extensive work of Fraunhofer, and later of Rowland, who definitely tabulated

the exact position in the sun's spectrum of an enormous number of distinct colors. These colors are referred to technically as lines. The extended Rowland table contains no less than 21,835 of these, of which 12,835 have been definitely identified as exactly like those which come from known earth-substances. The metals present in the sun in their order of abundance are magnesium, iron, silicon, sodium, potassium, and calcium, all of which are abundant on the earth. Those substances forming the greatest number of spectral lines are iron, titanium, chromium, cobalt, nickel, and vanadium. Among the most recently identified elements are atomic carbon, nitrogen, oxygen, and sulfur. Astronomers and physicists are still at work on this problem and doubtless many more elements will be identified in the next few years. The stars are not composed of materials foreign to us.

Stars vary in their distance from us from about twenty-five million million miles to a maximum of observable distance of five hundred million million miles. Their weight varies from as little as a millionth that of water per unit volume to a matter of several tons per cubic inch. Their diameters run from a few thousand miles across to several hundred times that of our sun, and their brightness varies from that of a flickering match to that of our most powerful electric arcs.

How can the stars vary to such an extent in density if their materials are those of the earth? We know of no material that even remotely approaches a value to be indicated in tons or even pounds per cubic inch. The explanation is based upon an interesting theory of the stars.

The only factor which stays within comparatively narrow limits for all stars is total mass. Here there is a variation of only a few hundred to one. Let us take this as our clew, for it has considerable significance. Temperature measurements of the stars, by means of sensitive electrical thermometers, show that they vary in temperature from 4000 degrees Fahrenheit to as much as 45,000 degrees. At such temperatures as exist at their centers it is obvious that all materials would become gaseous in nature. Ordinary hydrogen gas, at the temperature which exists in the interior of our stars, must travel at speeds easily approaching that of light. At these terrific speeds the atoms would be quickly broken up into their component parts, protons and electrons. These would be constantly bumping and recombining. We know that upon recombination the atom would emit radiation. Under star conditions these would be in the form of very short x-rays. As these started out from the center they would break up new atoms, and these, upon recombination, would again form radiation. This would be of slightly longer wave-

length then the first radiation, according to our theory based upon earth observations. Thus, as we go further toward the outside of the star, the radiations get longer and longer. It is the longest of those produced by the star which we are able to observe. The short waves are absorbed in the interior. We receive only the heat and light waves.

Will the Universe Completely Disappear?

If such a process is going on, we should expect that the stars would rapidly cool off. But observation has shown that they do not cool off with the rapidity which should be expected. This we now believe to be due to the possibility that the material of the star is itself being changed into radiant energy. This is not intended in the sense that coal is changed to radiant energy. Here the products of combustion could all be assembled and their combined weight would equal the original weight of the fuel. When matter is converted to energy in a star, the matter has been annihilated.

Suppose we attempt to make a star in space by combining positive and negative particles, those building-bricks of which all matter is composed. One positive and one negative will make a hydrogen atom. But we cannot have a star of hydrogen alone. We must build up some of the heavier atoms. The next above hydrogen is

helium. This has four negative and four positive particles in its make-up. Hydrogen has an atomic weight of 1.008. Helium has an atomic weight of 4. Yet helium has exactly four times the number of particles contained in hydrogen. If we put four hydrogen atoms together it should make a helium, but it will not weigh four times a hydrogen atom. If a pound of hydrogen were made into helium we would have 0.992 pound of helium and the remaining 0.008 pound of matter would have disappeared as radiation. This 0.008 pound of energy would be the equivalent of 430 billion horse-power. Thus, as we build up elements, the mass is partly dissipated as energy. Einstein has given an equation of direct equivalence of mass and energy. Because of this interchangeability, the sun will radiate for fifteen thousand billion years longer than it would if it were merely a cooling body. At the end of its life it will have completely disappeared. It will not be a cold body floating in space.

The basis for this radiation theory is supported by the small variation in total mass of stars, as already mentioned. Light exerts a small tho definite and measurable pressure. A body placed near one of these very hot stars would attempt to fall, due to the gravitational attraction, and would be repelled by the light pressure. It would take up a position of balance between these two and remain suspended in space. If a

star becomes too massive, the amount of radiation at its center will be so great that the outer material will be repelled from it. It might even break up with explosive violence. If the star is small, it will quickly cool. Thus the narrow limits between which the total mass falls gives a clue to the nature of mass and radiation. The splitting up of the star Nova Pictoris early in 1928 was ascribed by some astronomers as an explosion due to radiation pressure. There was, of course, much difference of opinion on this.

The fact that mass is continually changing to radiation would result in a complete annihilation of the universe if it were not elsewhere changing back to matter again. Experiments on cosmic rays indicate that this latter is occurring. Thus, if we do not ultimately have this universe, it appears that we shall have another fully as good, where the evolution of man may still go on. Now that definite boundaries have been set to our universe, we may still speculate as to what is beyond these when our present universe and its changes have been fully charted.

Astride a Light Ray to the End of Space

If we look at the summer sky on a clear evening, it has every appearance of a great dome studded with points of light of various brightnesses. We cannot, with the eye, determine anything of their distances. Do the brighter ones

appear so merely because they are nearer, or are they actually brighter? We can, by the usual methods of triangulation, determine the distance of some of the nearer ones. The method is a familiar one to all surveyors. But when we attempt to measure the distance of the farther ones, this method fails. The angles involved become too small for measurement. It is at this point that we must fall back on the brightness of the star itself for a measure of its distance from us.

A star may appear bright either because it is near us or because of its intrinsic brightness. A bright star is a hot star. As temperature increases, brightness increases. A piece of iron, when heated, becomes at first dull, then cherry red, gradually becoming whiter, until at its hottest we say it is white-hot. The same is true of a star. By measuring its degree of whiteness, so to speak, spectroscopically, we can thus tell whether it is truly a hot, and therefore a bright star, or whether it appears so because it is near us. This method has been developed into one which gives us very exact knowledge of star distances beyond that point where the method of triangulation is no longer of any value. By the use of these two methods we are able to map the universe.

A survey of the sky by the naked eye will perhaps reveal in the neighborhood of six thou-

sand stars. We see only the nearer and brighter ones. By the aid of a telescope we can increase this number to millions, for we can easily distinguish stars less than one-millionth as bright as the brightest of those seen with the naked eye. Our best telescopes, when used with photographic apparatus, bring this down to the ability to distinguish stars of one-hundred-millionth the brightness of those visible to the eye. With such instruments the universe has been largely charted. Let us see what we find.

Borrowing a method of description used by Professor Walter S. Adams, of Mount Wilson Observatory, let us follow the path taken by a light ray which begins its journey at our sun and travels outward with the usual light velocity of 186,000 miles per second. Such a light beam will pass our earth in about eight minutes. It will travel a lonesome path after leaving our solar system until it reaches Alpha Centauri, a dwarf star about as bright as the sun. This will be at the end of four years of travel. As it goes on, the ray will frequently meet with such stars as the one just named. They are scattered throughout space in every direction, but are too small and faint to be traced far with our telescopes. They are the local stops of our light ray. The first express stop would be the great white star, Sirius. The time-table shows that this would be nine light-years distant from our sun.

Calling only the express stops from here on, we find Vega, twenty-five years; Arcturus, forty years; the cluster of the Hyades, 130 years; the bright stars of the Pleiades and the belt of Orion, 500 to 600 light-years. From here on we are in unsettled country. The frequency of encounter with stars becomes less and less. At the end of 20,000 light-years we reach the first globular star cluster if we are traveling in the direction of the Milky Way, or if at right-angles to this, we are then reaching the boundaries of our star system. At the end of 100,000 light-years the light ray will find itself at the boundary of our own galaxy, or star group.

If it is our desire to proceed beyond this point, we shall next encounter certain star-clouds that are thought by some to have been broken off from our system of stars. Some of these that have been studied are from 100,000 to 700,000 light-years away. At 860,000 light-years we encounter Messier 33, and at 900,000 light-years the Andromeda Nebula, which appear to be nothing short of galaxies. Such galaxies have been studied as far out as 50,000,000 light-years, the distance of Coma Berenices, which has been studied extensively by Dr. E. P. Hubble. If you are exhausted by the journey through space at this rapid rate you will be pleased to know that you have now reached the boundary of our universe as far as it has been studied.

But is this the actual boundary, or are there, beyond this, other galaxies too distant for our present instruments to detect? Present theory would indicate that this is indeed the limit. Our universe appears to be curved, and, altho bounded, is infinite. It may be likened to a sphere. It has sharp boundaries, yet one traveling on it would never reach an end.

This view is supported by the fact that the most distant stars are apparently leaving us at a rate of several thousand miles a second. Either they are actually doing this, or the light is reaching us—according to theory—after it has passed around the universe. The latter seems the more plausible theory.

Beyond the limits of our universe we are never to see, provided it is thus bounded and curved. It will, accordingly, never be our privilege to know whether or not we are living in a universe or in a group of universes. This will be left to stir our imaginations long after we have discovered whether or not there is life on Mars.

Einstein Says the Universe is Curved

Suppose a stone is dropped from a moving train. To the man on the train observing it the stone appears to fall in a straight line. To a man standing on the ground the stone unquestionably travels a parabolic path to the earth. Both observers are right. The stone travels in a

straight line relative to the man on the train and a parabolic path relative to the man on the ground. All motion is relative. By a suitable system of coordinates all motions in the system of the stationary observer, no matter how complicated, could be changed over into the system of coordinates of the moving observer. In this way one could describe his observations to the other. These equations would be called the transformation equations. There is no fixed system of coordinates in terms of which all motion can be described. An observer off the earth would see occurrences on the earth in a wholly different way from the observer on the earth. Even the order of events might be reversed to the two observers.

These two observers are not even able to agree on time. Suppose they both stop and adjust their clocks so that the pendulums are swinging together. Now the moving observer sets off away from his friend with the speed of light. At once both decide that the other's clock has slowed down. The time between ticks will now be what it was before, plus the length of time required for the light to travel the distance which has been traveled by the clock since the last tick. If the moving observer turns around and approaches the stationary one, then the other's clock appears to each to be going faster than his own. He naturally believes his own to be correct,

altho the lack of agreement does not in reality exist. Neither clock has changed in the least. They only appear to have changed because of the relative motion.

The impossibility of our knowing anything of our surroundings absolutely can be illustrated in numerous ways. Let us take a familiar example due to the mathematician, Poincaré. Let us consider the plight of a group of individuals who can be assumed to live on a flat circular world whose temperature falls off as we go from the center toward the outer edge. Let us assume that all objects, including the residents of this world, contract in size with decreasing temperature in the same manner. Now, as one of these individuals moves outward he and all his surroundings decrease in size; his steps get shorter and shorter; he will never reach the edge. To him, his world appears infinite. To some one observing from the outside, it is finite; but an inhabitant may never learn of the boundaries. If he attempts to measure his universe, his measuring rods shorten as he goes out, much as ours shorten when we attempt to measure ether-drag. Examples can also be given in which an infinite world appears finite to its inhabitants.

Another factor which enters into relativity considerations is that of geometry. We are accustomed to the statements in Euclidean geometry that a straight line is the shortest distance

between two points, that the three angles of a triangle equal 180 degrees. These are true for the geometry of a plane. If a straight line and a triangle were drawn on a sheet of paper they could be wrapped around a cylinder or around a cone without distortion. The so-called axioms of plane geometry would still be true. But try to wrap the drawing around a sphere! This can only be done if we have used some material capable of being stretched. In this case we can fit the sphere closely, but the line and the triangle will have been distorted. If we now try to apply our laws of Euclidean geometry we shall arrive at peculiar results. We must accordingly revise our geometry. We must invent a spherical geometry. We might extend our systems of geometry to cover all sorts of cases. We might invent one that would apply to an egg-shaped object or even to a dumb-bell-shaped object. Such geometries become very complicated, but they are necessary to explain some of the results to which the theory of relativity leads us.

Plane geometry was invented by the Egyptians because of the necessity of annually resurveying the fertile land of the Nile Valley due to the seasonal floods. Plane geometry was all that they needed, for altho the earth was round, their measurements were on too small a scale to permit the detection of its sphericity by the surveying methods used. Had they measured over a suffi-

cient distance, however, they would have discovered errors in their work. These they might have attributed wholly to accidental errors characteristic of their methods, or they might have interpreted them as due to the earth's sphericity. They probably did not measure over distances, however, which led them into this difficulty. In much the same way we have never thought of the universe as curved. Exact measurements of which our modern astronomical instruments are capable have recently shown that stars near the edge of our universe appear to be traveling away from us with velocities of several thousand miles a second. It is necessary, because of this, that we either believe that we are the center of a great explosion or that space itself is curved. The latter seems to be the more reasonable assumption. We have for the first time made those measurements on the universe which the Egyptians might have made on the earth.

The theory of relativity leads us also to the conclusion that light itself has mass. If this is so, a beam of light passing near a very heavy object should fall toward it. This has been tested over and over again with beams of light from stars which pass close to the sun on their way to the earth. Because of the brilliance of the sun, this can be done only during an eclipse, when the light of the sun is obscured and the stars in its direction shine out clearly for a short time.

All measurements of this effect so far taken tend to confirm the theory, altho, because of the difficulty of making the measurements (there are many factors which enter to confuse the observer), it is still felt by many that additional data must be obtained before the theory can be accepted as a certainty.

The Long Arm of Astronomy Reaches Further

The era recently past has been marked, in astronomy, by the building and planning of instruments of much greater light-gathering capacity than have hitherto been used. Of these the sixty-inch reflector for the Harvard Observatory, Southern Branch, and the seventy-inch reflector built by the Bureau of Standards for Ohio Wesleyan University, are among the more notable. The two-hundred-inch quartz reflector to be built for Mount Wilson will, of course, eclipse both of these giants and start a new chapter in the history of astronomy.

The necessity for such instruments, if astronomy is to advance, is obvious. At the present time astronomers are working at the utmost limits of the accuracy of their instruments. Only a few of the nearer nebulæ are at present subject to study, and the more distant ones show no detail at all. They appear merely as star-like images. For spectroscopic study they require exposure-times of as much as one hun-

dred hours. The difficulty of making such long exposures is obvious; not every night is suitable for the observations.

What the 200-inch reflector will do for astronomy cannot be briefly described in more suitable words than those of Professor Walter S. Adams, of Mount Wilson Observatory, where the instrument is to be erected. Professor Adams writes as follows:

"The design of this huge instrument is being studied from the outset with a view to providing the greatest possible light-gathering power and efficiency to aid in the discovery and investigation of nebulæ and faint stars, the analysis of their light by the spectroscope, and the extension of the limits of space beyond those which can be attained with existing telescopes. The provisional design, to which much thought has been given during recent months, provides for a comparatively short focal length, about 3.3 times the aperture of the large mirror, to give great concentration of light, a fused quartz mirror to insure the quality of the images under varying conditions of temperature, and auxiliary mirrors to increase the effective focal length for such investigations as require higher magnifying power. Such a telescope would have a length of approximately sixty feet, a tube more than twenty feet in diameter, and a total weight of over 450 tons. The mirror itself, about three feet

in thickness, would weigh nearly thirty tons. The problems connected with the design and construction of this great instrument are such as to require the collective judgment of the most experienced engineers and instrument designers of the world. Similarly in the plans for its operation and the selection of the most fundamental problems for investigation, a very liberal attitude is being maintained by the trustees of the project to the end that its great possibilities may be utilized by astronomers in every field of research to which it can make notable contributions.

"On the basis of the performance of existing telescopes it is reasonable to conclude that the 200-inch reflector will multiply by a factor of perhaps eight the million or so nebulæ which we now know to exist. By about the same factor it will increase the number which can be studied in detail by the aid of variable stars and other recognized standards for measuring great distances. Stars of about one-tenth the light of the faintest stars we can at present see upon our photographic plates should appear on negatives taken with this instrument, and star-counts made from such records will amplify and improve greatly our knowledge of the structure and extent of our stellar system. What new methods for the study of the universes of stars may be developed through the immense light-gathering

power of the 200-inch telescope we cannot foresee, but from its use even with existing methods we can feel assured of discoveries of the highest value, ranging from the faint dwarf stars nearest to us to nebulæ whose distances approach comparison with the radius of our world of space and time.''

II

CELESTIAL PHENOMENA

Celestial Vagabonds

THE comet is often considered as the most awe-inspiring spectacle presented to man's gaze. Certainly, of the astronomical phenomena that we are privileged to observe, it takes rank with the total eclipse. Many of us still remember the last visit of the magnificent Halley's comet. Its long brilliant tail sweeping across the sky was an impressive sight. Small wonder that the ancients fell on their knees before their gods and prayed to be delivered from the impending calamity which the comet's appearance was thought to foretell.

Nowadays we can view a comet with somewhat greater calm, and speculate upon its cause and place of birth. Do these comets come to us from interstellar space? Are they mere casual visitors to our solar system, which appear century after century with the regularity of cosmic mailmen? This is the view frequently held. There is much to support the belief that they are, however, a part of our own solar system. They belong to us.

Against this suggestion is the obvious fact that they could not have been associated with the solar system from its beginning. No comet

could have survived for 10,000,000,000 years, the estimated age of the solar system. If they are members of the solar system they must have been adopted since its beginning. They must have been adopted not more than 1,000,000 years ago to be in the stage of development in which we find them to-day. By mathematical reasoning, F. Nolke has arrived at the figures 50,000 to 100,000 years as their probable age.

But there are other bits of evidence which help us to place the age and source of these celestial visitors. There is an absence of meteors in the earth strata below 1,000,000 years. There is a close kinship between meteors and comets; they are both stray members of interstellar space. Each may be responsible for the building up of the other. They differ chiefly in size. The absence of meteors in the early geologic formations has been given by some as a reason for belief in the theory that comets were originated by being thrown off from the earth's crust. It is equally a support of the capture theory.

The earth is moving at a rate of twenty kilometers per second. In 15,000 years it travels as far as light travels in a single year. It is moving in a direction away from the constellation Orion. A million years ago it must have been in the neighborhood of Orion, where it is suspected that there are large quantities of meteoric dust. It seems quite probable that it was here that

the earth acquired its comets. It has been suggested that the interposition of meteoric dust between the sun and earth accounts also for our glacial age.

All our comets are headed toward the same fate. They are becoming mere meteors. Their tails are becoming less and less bright. Eventually they shall have completed their life span. There is insufficient meteoric material to form new comets in the present position of the earth. No new comets are appearing. It has also been suggested that our asteroids, small comets of the solar system, are in fact dead comets.

It has been suggested by some, notably Sir William Herschel, that the comets might gather material in the form of meteors when far from the sun, thus adding to their mass. Evidence shows, however, that this is not likely to be true. They are becoming less and less impressive. They apparently are not the sky-brooms they were once thought to be. The fact that they are all of the same material indicates a similar origin for all, and likewise offers evidence against the acquisition of new material from the heavens.

Our Celestial Coal-Pile

It requires only that one be well away from city lights on almost any night of the year to see what are called falling or shooting stars. Especially after midnight one should be able to see,

on a clear night, as many as six or eight of these in an hour. These so-called falling stars are, in fact, meteors. They vary in size from small dust specks up to several tons. It is estimated that the earth encounters thousands of millions of such meteors each day, and that the sun encounters as many as a trillion per second.

Meteors are composed for the most part of such elements as silicon, oxygen, iron, and magnesium. Comet tails which contain many small meteors show evidence of containing carbon, hydrogen, and nitrogen, as well as cyanogen gas. Owing to the extremely high temperatures of the hot stars it is quite impossible that they should contain such substances as iron, magnesium, and cyanogen. Yet there is sufficient evidence in the absorption spectrum of the outer layers to assure us that these materials are present in very small quantities. The same is true of the sun. This suggests that interstellar space is infested with them, and that they are falling into the distant stars. It is the only way to account for the presence of these meteoric materials, which cannot long exist at hot-star temperatures, in these stars. Thus, altho we can actually observe meteors only when they are rendered white-hot by friction with the earth's outer atmosphere, we can be quite certain that they are colliding with the stars and the sun just as they are with the earth.

It might be argued that these materials are in the outer atmosphere of the sun and stars in an atomic and molecular state. If they were thus present as gases it is impossible to imagine them falling into the stars. They would be repelled by the pressure of the stars' light. As solid meteors, however, the situation is very different; they should fall into the stars with enormous velocities. It is estimated that meteors should fall into the sun with the stupendous speed of 400 miles a second. For the larger stars, velocities as great as 1,000 miles a second would be reached.

This constant bombardment of the sun and stars by meteors may constitute a celestial coal-pile that will prolong the life of the universe for many millions of years. This comforting thought is given to us by Dr. Harlow Shapley. According to the modern theory, already explained, the universe is gradually running down because of the transmutation of matter into energy. Computation shows that the sun is losing no less than 4,200,000 tons of its mass per second. This loss of mass will prolong the life of the solar system for many years beyond that which it would have if it were merely a cooling body. Now, with the sun collecting meteors at the rate of a trillion per second, we find that we have part of this loss made up. It is even possible, if the sun in its progress through space

should be fortunate enough to encounter a region in which the number of meteors was especially large, that it would gain in size. In other words, the coal bin of our solar system would be replenished for another few billions of years. That the sun might pass through such a region is quite conceivable. There is evidence to show that the system actually was in just such a region, in the neighborhood of Orion, about a million years ago.

Probably, by means of meteors and by the rebuilding of atoms from radiation, as evidenced from a study of cosmic rays, the running down of the universe may be delayed for an almost endless time.

The Moon an Earth Child

According to generally accepted theory, the moon was at one time a part of our earth, and, owing to some major disturbance, was disrupted from it. Having been thrown off, it has continued to revolve around the earth, held by the centripetal force. That this force will some day bring it back to the earth has been suggested, with good reason, by Sir Oliver Lodge. It may appear contradictory that once having been thrown off it should ever return. We must remember that conditions have greatly changed since that time, however. When the moon was born there is evidence to show that the earth

revolved at the rate of once in five hours, instead of twenty-four, as now. The moon, revolving around the earth and held by the centripetal force, is like a great ball being revolved at the end of an elastic cord. At high speed it will stretch the cord, but as its energy is gradually used up it will come closer and closer to the hand, and eventually fall into it. The moon's energy is being slowly dissipated. This dissipation is taking place in our daily tides, for example. Thus, as the moon's energy disappears, it will slowly approach and eventually reach the earth. Rather an unwelcome visitor!

If the moon is a child of the earth, certainly it does not resemble its parent. This is, in part, due to the difference in size. Because of this the gravitational attraction on the moon is only about one-sixth that on the earth. Even the most anemic person, if placed upon the moon, could perform marvelous feats, other conditions than gravity being the same. He could carry a load that would weigh half a ton here. He could jump six times as high as his earth record.

But all this glory will never come to such an individual. The moon has practically no atmosphere as compared with ours. He would find practically nothing to breathe. This is because the gravitational attraction is too small to hold an atmosphere. Here, in turn, enter other difficulties. The atmosphere acts as a great blanket

to protect us from extremes of heat and cold. When the sun was shining on the moon-dweller he would find the heat great enough to boil water in the open. When the sun was not shining he would experience a cold such as is impossible of conception on the earth. And since the moon revolves but once in twenty-eight days, he would have sunshine for fourteen days and darkness for an equal period.

Whether or not there is water on the moon is a question. Some have held that the moon is encased in a great ice shell; others claim to have detected snow in some of the craters. If water is present, it is doubtless frozen.

The cause of the moon's familiar craters is still unknown. One theory is that they are due to bombardment by meteors. This seems most unlikely, however, for the earth is also subject to such bombardment and we find but one crater, in Arizona, which resembles those on the moon. This one, if on the moon, would be too small for us to see. Those on the moon are as much as five hundred miles across, and are about ten miles deep. It seems more likely that they have been caused by some eruption remotely resembling one of our volcanic disturbances. The variation in temperature between the upper sunny portions of the crater's edge and the lower shaded portions is enormous. The material of the moon,

judging from temperature changes observed, appears to be much like that of our volcanic ash.

In ancient times the belief existed that the moon had a profound effect upon mankind. Insane people were thought to have been affected by the moon. They were called lunatics. Of late our artificial lights have made us less dependent upon the moon, and we have largely dismissed it from our thoughts. We are now coming to believe, however, that it has more effect upon us than we have recently supposed. It will be more important to us in the future. Doubtless the tides will eventually be harnessed for power purposes. Plant growth, once thought to be affected by the moon, has in fact been found to be so to some extent. This is because the light from the moon is largely polarized. It has a tendency to vibrate all in one direction instead of haphazardly. A close study has shown the moon to have an effect upon animal life as well, particularly upon reproduction. We may yet find some of the old traditions of our forefathers, lately scouted, put upon a firm scientific basis.

Can a Light Ray Bend?

There is nothing mystical about an eclipse. The moon merely gets between the earth and the sun, and obscures the sun's light. The effect is, however, thrilling, and it is not surprizing that the uneducated people of a few centuries ago

were terrified. To see the stars appearing in the middle of the day, to see the fowl go to roost, to see the wild birds circling in confusion, is a sight long to be remembered. As the wave or ripple-like shadows chase over the ground, and one experiences the sudden chill that comes with a slight tho rapid decrease in temperature, one cannot resist a feeling of awe. If one is located so as to see the edge of the shadow approach at express-train speed, the sight is even more inspiring. Then, after all is darkness, to see the sun suddenly burst out from the moon's edge in a wealth of splendor, makes one to feel in oneself something of the sun's triumph over its brief eclipse by the moon.

To the astronomer an eclipse offers an opportunity to study many things not ordinarily afforded him. He travels to a far corner of the earth and spends months preparing his apparatus and rehearsing over and over again the measurements he is to take. As only a few brief minutes are afforded for the work when the time comes, any error is costly. That particular eclipse will never occur again, and every scrap of data is valuable.

One of the things of major interest is the sun's corona. This is composed of luminous gases and extends out from the sun's surface for several hundred miles. Normally these gases are impossible of study because of the brightness of the

sun's disc adjacent to them. An eclipse offers an opportunity to study them without this handicap. Of recent years much interest has been centered upon the confirmation of Einstein's theory that light has mass. If this is so, the light from stars which must pass close to the sun on its journey to the earth should be bent toward the sun. Light from such stars, of course, cannot be seen when the sun is not obscured by the moon; but during an eclipse they stand out clearly. All the evidence so far collected points to the correctness of Einstein's theory, but there are so many factors which might produce a confusing effect, such as refraction of the light by our own atmosphere, that the conclusions are not accepted by all. Further data are desired.

The cause of the wave shadows that race across the earth during an eclipse is now understood. The shadows are produced by the changing temperature of the atmosphere, owing to the obscuring of the sun. Such temperature changes cause refraction, a bending of the light path, which produces the shadows.

The rate at which the sun's corona changes its shape is still an unsolved problem. So far, no two eclipse stations have been far enough apart to note this change and to measure the time required for it to take place. Of course, it changes from one eclipse to another, but these happen years apart. During recent eclipses attempts

have been made to measure this change, but without success. One or other of the stations usually experiences cloudy conditions. Doubtless in future eclipses more definite knowledge will be obtained regarding this particular phenomenon.

Man Marks Time

The exact measurement of time is the business of the astronomer. It is he who keeps our clocks correctly timed. Without him we might easily wander far from the correct values. In the early days of civilization the passing of time was marked by observations on the moon. The rising or setting of the sun one day was very much like that of another, but the moon's phases were easily recognized. Time was recorded, as a rule, by some simple method, as cutting notches in a stick. This was so in Egypt, in China, in Assyria, and with the American Indian. In the second stage of the development of the calendar, counting stages of five moons was developed. This was because the medium of trade and exchange was largely sheep and goats, and five months is their breeding period. As this wandered from synchronism with the seasons, the counting of six moons soon resulted—six for summer and six for winter. This coincided roughly with the year as marked by the sun.

The building of pyramids and obelisks, some writers believe, was due to a desire to measure

the year more accurately. Knowledge of the times and causes of the changing seasons certainly was a large factor in the superior agricultural position of the Egyptians, and the calendar thus determined was carefully guarded. Only the priests understood the measurement of the passage of time. It was they who announced the holidays, days of planting, and so on. In this way the farmers were not fooled by a few warm days into too early planting, neither did a backward spring mean that their crops were ruined at the end of the season. Among the Egyptians, not one person in 100,000 was ever allowed to see the calendar records. This jealously guarded knowledge gave Egypt an advantage over less informed nations.

The observations in Egypt were gradually replaced by more exact observations on the stars. Eventually a calendar was adopted having twelve months of thirty days each. The extra days of the year were devoted to a holiday period.

The conquest of Egypt by Julius Cæsar led to the adoption of a modified form of this calendar by the Romans. Alternate months were given an extra day to make thirty-one, except February. This month, which ended the year, had but twenty-nine days. This, while not as desirable as the Egyptian system, was a great advance for the Romans; for at that time their calendar was

three months off with the seasons, due to the falsification of records by politicians for the purpose of prolonging their terms of office.

Augustus Cæsar further spoiled this calendar by renaming Sextiles in his own honor and selfishly extending its length to equal that of the longest month—thirty-one days. A day was taken from February, thereby spoiling the quarterly system. It left the first quarter with ninety days and the third with ninety-three. This led to considerable juggling of the calendar. A day was taken from September and given to October. Then one was taken from November and given to December. Thus arose our awkward months, which are supposed by many to be as sacred as if handed to us by divine authority.

About three hundred and fifty years later the seven-day week was introduced, and the days were named for the first time. Up to 1582 the calendar was based on a year of exactly 365.25 days. At this time it was found that the accumulated error amounted to ten days. These were dropped between October 5 and 15 of that year, and our present leap-year rule adopted. The Protestant parts of Europe did not drop these days until 1752, when Great Britain and Ireland dropped eleven days in September. The Greek calendar, differing from ours by thirteen days, was used in some parts of the world up to 1919.

Our present calendar is indeed an awkward

affair. Neither its months nor its quarters are equal. Anniversaries, interest dates, and so on, fall on different days each year. The varying length of the months is perhaps the most annoying factor, however. There is a difference of eleven per cent. in the lengths of February and March, and a difference in the number of working days of 19 per cent. This leads to considerable difficulty in accounting, in comparison of month-to-month statistics. Especially does this raise difficulties for corporations that have most of their business falling on certain days of the week, as on week-ends, for example. Some months have five Saturdays, others have only four. This is decidedly awkward for concerns which pay their employees weekly and conduct their own finances on a monthly basis. All these things lead to heavy accounting expenses. There is a constant cost in providing new calendars and a loss of time in consulting them.

Because of these objections there has been agitation for calendar reform. It has been suggested that each quarter consist of two months of thirty days each, and one of thirty-one. Another suggestion has been that each quarter consist of three months of thirty days each, the extra day being undesignated and used as a holiday. A third suggestion would give us two months of four weeks and one of five weeks each quarter. The last and most favored suggestion is that the

year be divided into thirteen months of twenty-eight days each, a month to be called Sol being inserted between June and July. This would leave an extra day each year, which, it is suggested, would be called Year Day and have no designation other than that of the year. It would follow December, except in leap year, when it would follow June. This calendar, due to Moses B. Cotsworth, is known as the Cotsworth calendar. It is the calendar favored by the National Committee on Calendar Reform, and will probably be this nation's recommendation to the League of Nations Committee. The most suitable year to adopt this calendar would be 1933, the next year to begin on a Sunday.

III

THIS EARTH OF OURS

The Sun's Children Are Born

WHERE did the earth come from? What was its origin? How long is it likely to be here? All perfectly natural questions for the person to whom the answers may mean life or death. In the past we have had many theories as to the birth of this earth upon which we find ourselves, and many of them were extremely fantastic and imaginative—a fact not at all to be wondered at. As science advanced, such theories as the fall-from-infinity and the planetary-ring hypothesis were advanced. Then there were the theories of a star collision with the sun, and the nebular hypothesis. The latter was common in our school-books of the early twentieth century. Most of these theories have now been pretty well discarded, and while there are those who do not agree with the planetesimal theory as advanced by the late Thomas Chrowder Chamberlin, who was for many years head of the Department of Geology of the University of Chicago, it nevertheless has a sufficiently wide acceptance to justify its appearance here.

According to this theory, the planets are the offspring of the sun, their other parent having

been a star which, through chance, came into the gravitational field of the sun, and which is now, in all likelihood, cold and existent only among star wastage. This parent star did not form the planets by directly hitting the sun; but, being near the sun, it had the effect of drawing out from its molten surface in cone-like protuberances that material which was to form the planets. The actual birth of the planets was due to the propulsory power of the sun through eruptions, light push, radiation, magnetism, and electrical discharge—forces almost equaling its gravitational attraction—and the combined repellancy and attraction of other stars.

According to our latest knowledge of the dynamics of such occurrences, the cones pulled out from the sun would each result in a double explosion. A large mass would shoot out toward the star, and a smaller mass would shoot out from the opposite side of the star and travel in the opposite direction. Four such double explosions would form the four major and the four minor planets. Not having enough energy to pull these masses into itself, the star appears to have had sufficient to set them in motion on a near-circle around the sun. Dynamics also tells us that these planet bolts shot off the sun would emerge with a spiral and vortical whirl, which would later assist them in gathering around a

solid core. (The center of the earth is now believed to be solid, not molten, as long supposed.)

Without the passing star, the formation of planets from eruption of the sun would have been impossible. Normally, material shot off from the sun would be dispersed and would eventually fall back into the sun again. The star gave the erupted material great mass and a spiral motion, which made the formation of planets possible. The birth of planets such as ours can thus be the result only of the rarest kind of accident. It is estimated that the close approach of a star, such as seems to have occurred in this case, can take place on the average only once in a quadrillion years. On this basis another similar close approach, which might destroy our earth, is not due for an inconceivably long time. At the present time none of the stars seem to be headed in our direction. Our race will perhaps be wiped out by other circumstances long before this will occur.

The satellites are explained on this theory as offshots from the main bolt of matter shot out on each explosion. They are thought to be due partly to separate eddies or whirls on the outside of the molten planetary material, which were separated from it by the drag, and partly to secondary eruptions from the main mass. They succeeded in getting far enough from it to form their own cores, but not far enough to escape

from the gravitational field. They were thus held revolving around it. Abandoning the old theory that the moon presents only one face to the earth because of tidal influence, the new theory holds that this is because the moon is not symmetrical, but is heavier on one side than on the other. Gravitational attraction accounts, then, for this heavy side being always toward the earth. The same explanation is given for the similar behavior of Mercury and Venus, which always present the same side toward the sun. The strange behavior of some of the satellites of Jupiter and Saturn, which revolve around their planets in a direction retrograde to that of all others, is accounted for on the theory that their direction was reversed by a collision with the central mass. Failure of the nebular theory to explain this was its undoing.

"Nothing whatever has been found in the record to imply that the birth of the earth was a feature of the absolute beginning of the universe," says Professor Chamberlin. "The inquiry has led to the impression that the creation of our planetary system was but an incident in the history of our sun, while even the genesis of the sun might not improbably be but an incident in the history of our stellar galaxy." The birth of our earth was but a minor affair in the history of the universe, and it is quite unlikely, as Professor Chamberlin put it, "that

even the star neighbors felt any 'thrill' by reason of the event."

We Live on a Hot Steel Ball

What is in the interior of the earth? It is a difficult question to answer. Strange to say, we actually know more about the contents of stars millions of light-years away than we know about the earth on which we daily tread. The Abbé Th. Moreau, Director of the Observatory of Bourges, writing in *Le Petit Journal,* said: "In the present state of human industry we cannot think of exploring the earth's entrails directly. The greatest depth realized is that at Olinda, California. Rocks have been brought up from 2,460 meters below the surface. But what are three kilometers to the 6,371 which must be traveled to reach the center of the earth? A simple scratch."

Obviously, then, we must gain all our knowledge of the earth's interior indirectly. We have not at hand the mechanical means to penetrate far enough into the earth to do more than this. We find for our purpose but two sources of information. The first is the volcano, which has supplied us with valuable data, altho often at the most inopportune times and in a highly undesirable manner. The other is the temperature measurements made in deep oil wells.

Study of oil wells has shown that there is a

considerable increase in temperature with depth, tho the increase varies with the locality. In South Dakota the increase in temperature with depth varies from one degree Fahrenheit in forty-five feet to one degree in twenty feet. At Fairmont, West Virginia, a temperature of 175 degrees was found at the bottom of a 7,500-foot well, while at Longmont, Colorado, a temperature of 212 degrees was found in a 6,600-foot well. Based upon the temperature-rise of the last 1,000 feet of the seven deepest wells in the United States, an estimate of the temperature at the center was given by the publication *Tycos* as 443,000 degrees Fahrenheit.

That such a temperature is at all probable at the earth's center is admittedly preposterous. The temperature certainly could not go on increasing at the rate given. To measure the rate in the first three miles and assume that it continues is much like measuring the rate of growth of a child in its first few weeks and assuming that it will continue to grow at this rate until it is eighty years of age. In this way we would compute into existence a race of giants. The outside temperature of the sun is only 11,000 degrees Fahrenheit, and while its center may be much hotter, it is doubtful if the interior of the earth reaches a figure greatly above this.

If we go down to the birthplace of volcanoes, about twenty or thirty miles, and assume that

for this depth the temperature increase is at the rate observed in the previously mentioned deep wells, we shall arrive at a temperature high enough to melt lava—some 3,000 degrees. We might now assume that the interior temperature remained the same everywhere below this thirty-mile crust, as in a liquid, where temperature differences quickly smooth themselves out through convection currents. But the interior of the earth, from a study of its rigidity, weight, etc., appears to behave like a solid steel ball. This is quite possible, even at temperatures well above the melting point of the earth's materials, because of the enormous pressures which must exist inside. If, now, we regard the earth as a solid, a temperature equalization in the interior is decidedly unlikely. It would require centuries for a molecule at the center to wend its way to the surface. The interchange of kinetic energy, which is the temperature-controlling factor, between inside and outside molecules would be an extremely slow process.

On the other hand, there are those who believe that the interior of the earth is a cold solid. They believe that the temperature-change which is found as we go down in deep oil wells is due either to the presence of radioactive material or to chemical changes which are in progress in the oil. It happens that there is about enough radioactive material in the earth's crust to make

this a plausible theory. That there is some basis for the contention that the heat in oil wells is due to chemical action is also true. The rate of increase in oil wells with depth appears to be much greater than where oil does not exist. In fact, this has been suggested as a method of prospecting for oil. To account for the heat of the volcano, these people contend that the volcanic material is normally cold and that the heat is generated when pressure is relieved by rock-slippage. The reduction of pressure allows certain heat-producing reactions to go on, which at normal pressures are impossible. The heat is thus a local product of chemical action.

We are left with the obvious conclusion that we know but little of what is below the crust upon which we daily tread. Perhaps if we knew more of what is under us we should be less at ease.

The Age of the Earth

Man has long been curious enough to wish to know the earth's age. The earth has, on her side, kept the secret well. We can make our scientific guesses—no one can deny us that privilege—but after all we can reach only a very limited degree of certainty. In the end, the ingenuity of the methods employed is found to be of more interest than the results obtained. In all these guesses we are concerned with the age of the

earth, computed from the time the crust formed. We are not interested, for the moment, in how long it may have existed in the molten state, or how long it was previously a part of the sun.

The first of these scientific guesses to deserve our attention is that of Lord Kelvin. His estimate is based upon the present rate of cooling of the earth's surface. This gives an approximation of the time which must have elapsed since it was a molten mass. We can estimate what its temperature must have been at that time. Lord Kelvin's first conclusion was that the age was between 20,000,000 and 400,000,000 years. He later reduced the maximum figure to 40,000,000 years. This figure did not meet with approval of zoologists. They did not believe that it was long enough to have permitted of the great changes which had been found in animal life in the process of evolution.

Further estimates were obviously in order. A computation of the amount of salt in the ocean as compared with the amount poured into it annually gave the age as about 350,000,000 years. But who can say that the ocean did not originally contain some salt? Estimates based upon the rise of the deltas in the Nile and Mississippi Rivers—on the retreat of Niagara Falls—on the retreat of the glaciers in Sweden after the ice age—are likewise open to objection. There are

many factors which might have influenced these occurrences outside of time alone.

Our most modern method comes from the study of radioactivity. The parent radioactive material, uranium, like its children, goes on constantly disintegrating. In this process it gives off the primary electrical particles—electrons—and helium. As it looses this material it passes through transitions from one material to another and finally becomes radioactive lead. Here the process of natural transmutation stops. Nothing that man has ever been able to do has changed the rate of this process. He has tried the very extremes of temperature available to him, the highest voltages that he is capable of producing, but always failed to change the rate of disintegration in the slightest degree. It is safe to assume, therefore, that no changes on the earth's surface since its crust was formed have been of sufficient intensity to make any change in this disintegration rate. Assuming, then, that this rate of disintegration has been always constant, the percentage of lead found in a sample of uranium should give us the means of determining how long this disintegration has been going on. Such estimates indicate that the youngest rocks of the earth have existed for 1,000,000,000 years, and credit the earth with a minimum existence of from 2,000,000,000 to 8,000,000,000 years.

Writing in *De Telegraaf,* Professor W. J. Luyten compares the period of the entire existence of life on the earth to a day of twenty-four hours. On this basis he says:

"The greatest period, that is the longest life, must be accredited to the most primitive creatures in microscopic form. They lived twelve and a half hours by this time. The life of fish has lasted now for eight hours, that of reptiles two and a half hours. The mammals aren't supposed to have existed for more than three-quarters of an hour, and man only two minutes. When one considers that our 'civilization' began 6,000 years ago, then we must admit that it really makes up no more than four seconds of that entire day of life, and that our modern industrial period makes up only one-tenth of a second out of that day. However far man's existence may seem to date back as a 'civilized' creature, man has yet hardly been weaned."

Man Weighs the Earth

We may find ourselves balked in our attempts to discover what is inside the earth. We may arrive at a very indefinite conclusion as to its age. But there is one thing that we can do which at first hand would appear at least as difficult as either of these. We can weigh it. Archimedes is said to have claimed that, given a place whereon to stand, he could move the

earth. How many tons would it have been necessary to move? He did not know just what such a contract would have called for. We do. The weight is six thousand million million million tons. It is actually known more accurately than this, but the total given is approximately correct.

To ask just what good it is likely to do anybody to know this is a legitimate inquiry. It is useful for two reasons. It is one of the things that inform us, to some extent, of the earth's interior. We find that the rocks forming the earth's crust are from two to two and one-half times as heavy as water. The density of the entire earth as computed from its weight and size is twice this. This leads us to the remarkable conclusion that its interior is a solid iron ball, which is further confirmed by the fact that other heavenly bodies, meteors, which sometimes land on our earth, are so constituted.

Again, this knowledge of the weight of the earth is important to astronomers. In their study of stars and planets the weight of the earth is frequently of value—especially so in computing the weight, orbits, time of revolution, etc., of the other planets.

How can we weigh the earth? In principle the experiment is very simple, altho, in actuality, to obtain accurate results is exceptionally difficult. The simplest method is that of the pendulum. This method is used at the United States Bu-

reau of Standards. The experiment is performed by setting up what might be referred to as a miniature earth. Two large steel balls weighing 140 pounds are used as artificial earths. Between these steel balls two gold balls, weighing an ounce and a half and fastened at the ends of a light platinum rod, are suspended by a thin tungsten fiber. The gold balls are set swinging and their periods of swing measured. The weight of the steel balls and their distance from the gold balls determine the period of swing. So sensitive is this arrangement that the presence of a person as much as ten feet away will cause a variation. Because a car moving outside the laboratory would affect the precision of the result, the apparatus is located thirty-five feet below ground level. The attraction of the steel ball for the gold ball is only in the neighborhood of a millionth of a grain or about a thousandth of a milligram. By repeating the experiment with the steel balls at different distances the constants of the apparatus can be measured. It remains, then, only to determine the attraction of the earth for the gold balls and to know the distance between the center of the balls and the center of the earth. The problem is one of substitution in a proportion. The attraction depends upon the product of the two masses and inversely upon the square of their distances apart. Therefore the mass of the earth is to the mass of the steel

ball, as the attraction of the earth times the square of the distance between centers of earth and gold ball is to the attraction of the steel ball times the square of the distance between steel and gold balls. The arithmetic is simple. The experiment is rendered difficult by the necessity of putting the vibrating gold balls in a vacuum chamber to eliminate the effect of air currents, the necessity of avoiding vibrations, and by many other troublesome factors. The work at the Bureau of Standards is being carried to greater accuracy than exists at present by Dr. Paul R. Heyl.

IV

SURFACE DISTURBANCES OF THE EARTH

The Earth Has a "Blow-Out"

THERE are probably few experiences more terrifying, if one is to judge by descriptions, than to be in the neighborhood of a full-fledged volcano in eruption. Yet there is perhaps nothing more necessary than such eruptions when one considers the general good of all earth-inhabitants. A volcanic eruption is a blowing off of a great safety valve.

There is a decided sameness to all volcanic eruptions. Throughout the centuries volcanoes have belched forth the same kind of magma, and records of the temperature of this has shown it always to be within the narrow limits of about 1,000 to 1,500 degrees Centigrade. On the assumption that the interior of the earth was molten, this was difficult to explain. It was assumed that it all came from the same interior reservoir, the temperature and contents of which were the same throughout the time considered.

But now we know that the interior of the earth is solid. We know that there is a gradually changing condition as we go down. We now assume that at the depth of volcanic origin, twenty or thirty miles, there exists, not a reser-

voir of molten material, but a chemical and physical condition which gives rise to volcanoes. At this depth it is assumed that the materials are solid, not because of low temperature, but because they are kept solid in spite of the temperature by enormous pressures. These pressures we cannot hope to approach in the laboratory, yet at 20,000 atmospheres (about 300,000 pounds to the square inch) gasoline becomes as viscous as vasoline, and wax becomes rigid.

The condition which is immediately responsible for a volcano is thought to be a slippage of the rock formation, perhaps due to immense loads of sediment which accumulate on the ocean floor. The displacement of the crust by a mere fraction of an inch would result in enormous pressure changes within the earth.

With the formation of a fissure or crack in the rock which forms the earth's crust, there is at once afforded a means whereby the magma can begin to force its way slowly toward the surface. Throughout the journey the temperature remains high, because the rocks with which the effluvia come in contact are poor conductors, and also because there is still contact with the hot magma below. If the volcano is an old one, the rocks are already heated and the moving material falls very little in temperature. With the release of pressure the magma gradually be-

comes molten and eventually flows over the side of the volcano's crater.

In the case of an explosive eruption there are some other factors at work. First come great quantities of steam. This is due to the magma encountering water on its way to the surface. The explosive character of water which strikes a hot surface is well known. After the steam comes gas. About a third of this is hydrogen, one of the most explosive of gases. This is accompanied by phosphorus and other dangerous materials. In addition we may have profound chemical action between materials in the magma itself. Materials which under pressure in the interior of the earth might lie side by side without reaction may, when liquefied, become intensely active. Also the gases dissolved in the magma may rush to the surface, giving the effect of opening a giant bottle of carbonated water.

As a result of this explosive action we find stone so inflated with gas-bubbles that it will float—pumice-stone. We find the lava blown to a fine dust, which sometimes obscures the sun. This dust has been known to spread in the upper atmosphere around the entire earth, and, by shutting off some of the sun's rays, to lead to a cold period lasting several months.

Accompanying the eruption there are usually earth tremors. These might well be expected,

both because of the violence of the eruption and because of the origin of the eruption as well. Severe lightning storms also are common during an eruption. This may well be due to the electrification of the lava dust and of the gases as they are shot upward through the air. Electrification will result from the friction between the gases.

After an eruption has subsided there is still danger left. This is in the poisonous gases that are given off. Sulfur gases appear first. On further cooling, water vapor, hydrochloric acid, sulfureted hydrogen, and chloride of ammonia are given off. Finally carbonic acid is given off, and this, being heavy, collects in valleys and low-lying ground. It results in the so-called poison valleys. Some volcanoes have a predominance of the one or other of these gases.

A volcanic region eventually becomes one of geysers and hot springs.

The Earth Shakes

The cause of earthquakes is like that of volcanoes—rock slippage. If we were to investigate it further it would lead us to an examination into the cause of the slippage itself. Of this there have been many theories. One has it that the slippage is due to an actual shrinkage in the earth's surface as the earth gradually cools inside. Then there are those who believe that

earthquakes are due chiefly to the piling up of sediment on the ocean's floor, resulting eventually in such a load that the crust of the earth can no longer support it without some readjustment. This results in a series of disturbances. Others would suggest that earthquakes result from earth-tides, which gradually mold the earth's surface until it reaches a point where a sudden crack or slippage takes place. Others claim to see a close parallel between the sun-spots and periods of earthquakes. Just how a sun-spot could so profoundly affect the earth's crust is indeed difficult to see, and yet data have been found which indicate a parallel between these two phenomena. Perhaps we may be more nearly on the safe side if we suggest that all these things may contribute to the beginnings of an earthquake.

The one bit of earthquake information that is least known to the layman, apparently, is that earthquakes in any locality are almost continuous. The earth is almost constantly trembling. At any seismological station large numbers of quakes are registered daily. Most of these, however, cause no more vibration than is caused by a truck a block or so away. They are easily distinguished from the latter by the trained seismologist with the aid of his sensitive instruments. At the same time there are few days when a seismic station does not register what

is called a major quake—one of sufficient intensity to give data worth communicating to other stations.

In addition to the almost constant trembling of the earth there is also often indicated a tilting of the earth. This is, of course, a local effect, thought to be due to the piling up of great masses of water on the beach at high tide. The same local tilting can be observed when a large number of persons visit a seismic station. The tilting is extremely slight, and only the very sensitive instruments of the seismic station would be capable of detecting it.

It is enough to say, perhaps, that a few hours at a seismic station watching the records would convince any one that this earth is not the solid, steady planet which we ordinarily think it is.

Exploring the Atmosphere

Surprizing as it may be that we know so little about the earth beneath us, it is equally, if not more surprizing, that we know so little of the atmosphere above us. We do not even know how high it extends upward from the surface of the earth. Confronted with the question, one usually answers thirty or forty miles. It is difficult to find any justification for such an estimate. The answer probably depends upon what we mean by the earth's atmosphere. Would it be correct to say that it extended only to that

distance inside of which it is capable of supporting life? Then it extends only a few miles, perhaps three or four. Or should we define it as ending at that point at which no gas is present? To estimate where this would be is quite impossible. And yet if this is not the point at which it in fact ends, then it is difficult to select any other more suitable point.

Suppose we decide to say that the atmosphere ends where pressure-gauges, regardless of their sensitivity, no longer register any pressure. The pressure is zero. How can we determine where this point will be? Certainly we cannot reach it by airplanes, dirigibles or balloons. To go up even three or four miles an aviator requires enormous preparation. He must carry oxygen to breathe, electric heaters, both for himself and to vaporize the gasoline, and so on and so on. The intense cold and the rarity of the atmosphere make it out of the question to attempt to go much higher than this. Dirigibles and balloons are even more hopeless. They depend upon the buoyancy of the air to lift them, and, as this air becomes rarer at high altitudes, they are unable to rise. Perhaps rockets, which do not depend upon the air but are in fact hindered by its friction, will eventually be used to explore the upper atmosphere. In the meantime we must depend upon computations.

Now, computations of the height of our at-

mosphere are extremely difficult to make. There are many factors which complicate the problem. The air is composed of many gases, it is compressible, and it has weight. The rotation of the earth is another troublesome factor. Further, the temperature of the atmosphere is different at different levels. The particles of gas are always in violent agitation.

The only data that give us much assistance are those of atmospheric pressure. Air, tho very light, has weight, and there is enough of it above us so that, due to its weight, there is a pressure upon us of about fifteen pounds per square inch. Our bodies are made to withstand this pressure, and if the atmosphere were suddenly removed we should doubtless explode. If it had no weight there would be nothing to hold it to our earth, and it would soon disappear into space. As conditions are, it would be necessary for a particle to acquire a velocity of 25,000 miles an hour to escape from the earth.

If temperature were the same at all heights and we had but a single gas to deal with, we could at once compute its height from its weight per square inch on the earth's surface. But it is composed of several gases and we do not know how much of each. It takes an eight-mile column of hydrogen to weigh as much as a single mile of oxygen. Then, too, there will be variations in

the temperature as we go up, a factor of which we know almost nothing.

We know also that if we rapidly rotate a wet ball, the water will collect around its middle, or equator, and will fly off from this belt. In the same way our atmosphere tends to collect at the earth's equator. The air-layer over the earth is thus greater at the equator than at the poles.

Why should the temperature fall off as we go up? It would appear that the sun's rays would be stronger higher up, as they have not been absorbed by the atmosphere as much as have those which reach us. The answer to this is that most of our heat comes from absorption by the ground. Many of the sun's rays absorbed by the earth are reemitted as heat only to be again absorbed by the atmosphere within a few meters of the earth's surface. The atmosphere thus acts as a blanket to keep the heat in. The effect is much like that of a hothouse. If it were not for this blanket the temperature of the earth would be about sixty degrees below zero.

It is also sometimes difficult to see why the air, having weight, does not fall at once to the earth. Failure to do so is due to the rapid molecular motion of the air particles. These particles have a trembling motion of enormous velocity. They are constantly striking and rebounding from each other. The velocity of oxygen at normal temperature and pressure is about a quarter

of a mile per second. Hydrogen has a velocity of about a mile a second. It is the impact of molecule against molecule at this enormous velocity which holds them apart and in the gaseous state. If the temperature were reduced so that they slowed down they would fall to the earth as a liquid. Or if they were slowed down to an even greater extent, the earth would be covered with but a few feet of solid air. To accomplish this a temperature of nearly 460 degrees below zero Fahrenheit would be required.

In spite of all the information which we have concerning gases, we must still admit that we know very little about the atmosphere above us.

Major Earth Winds

In a study of the earth's atmosphere we are also confronted with the regular air currents or winds which keep it in a state of constant motion. Chief among these steady winds are the so-called trade winds, which are to be found at the equator, and with which every school-boy is familiar because of their important bearing on the voyage of Columbus. Then there are the prevailing westerlies with which we have all recently become familiar because of the obstacle they present to east-to-west trans-Atlantic flights by airplane. Both of these familiar air currents are due to the same cause.

Every one knows the fundamental principle

of physics which says that heated air, because it is rarer and lighter than cold air, rises. It is this fact which is put into practise in hot-air furnaces used in small buildings. Now the air at the equator, being heated, will rise, and air from both north and south must come in to take the place of this air. Having risen, the air is away from its source of heat, which is the radiation of heat due to absorption of sunlight by the earth. It consequently cools and falls again, farther north. Part of it will again blow toward the equator, while part will continue north.

Now, if the earth were stationary this would result in north and south winds only. But the earth is rotating. It is often believed that it is this rotation, dragging the air after it, which gives the wind its easterly direction at the equator. If this were the case, all winds should have such a direction, while as a matter of fact the winds in the temperate zones are westerly in direction. The true cause for the veering of the winds from straight north and south is a gyroscopic action due to the earth's rotation. The peculiar behavior of such action is easily imagined by any one who has ever played with a gyroscopic top, a toy which behaves in a most uncanny fashion. The principle which determines the direction of the winds is utilized commercially in the gyroscopic compass.

The result of the convection currents and the

gyroscopic action is a wind blowing toward the equator in a southwest direction, north of the equator, and in a northwest direction south of it. As the air which rose at the equator falls again in the north and south hemispheres, there is created an almost windless region in each, known as the doldrums. North of this, in the northern hemisphere, the wind has a northeasterly direction, and in the southern hemisphere, south of the quiet region, the direction is southeasterly. In addition to these main winds there are the circumpolar winds.

While local disturbances close to the earth do not always permit these winds to be recognizable, their presence is none the less obvious. If one observes the cirrus clouds, which are several thousand feet above the earth, one will find that in the northern hemisphere they are always traveling toward the east. Their velocity is usually from twenty-five to fifty miles an hour. It is the existence of these winds upon which our whole system of weather prediction is based. That their velocity is not great is due to friction with the earth. Were it not for this factor the velocity of the wind would probably reach thousands of miles per hour. In the southern hemisphere, where the obstruction by land is not great, these winds do in fact reach considerable velocities. Their intensity at about the fortieth

degree of latitude, in the southern hemisphere, has resulted in the phrase "the roaring forties."

A complete study of our winds has yet to be made. At present we know only what is happening near the earth. Air cannot always blow in one direction. It must get back somehow. Thus, while the wind is somewhat toward the north at all points in the northern hemisphere, it certainly does not pile up at the pole. There must be counter-currents higher up. Perhaps if we knew where these are, airplanes might cross the ocean as easily from east to west as from west to east. It is thought that such a current may be sandwiched in as a narrow ribbon from 6,000 to 10,000 feet over the Atlantic.

The airplane now demands a more thorough study of these air-currents and this study will doubtless be made through the release of small sounding-balloons. At the present time we are surprisingly ignorant of all but the most obvious.

Weather Prediction

All clouds are the result of the condensation of moisture from the atmosphere. At any particular temperature there is a limit to the amount of water which the air can hold, and any decrease in temperature will immediately result in condensation and the formation of clouds.

In warm places there will be formed convection currents of air which rise rapidly and carry

with them the moisture due to evaporation from the ground. As these currents reach the cooler regions higher up the moisture will condense to form a cloud at the top of the column. Such a cloud will be a cumulus cloud, one of the large billowy kind which one so often sees floating lazily across the summer sky. Such clouds are fair-weather clouds and bring rain only when they have reached an abnormal thickness. This thickness will depend upon the temperature. In winter a thickness of about 300 feet will bring precipitation, but in summer the thickness must be much greater than this to bring rain.

The formation of these clouds by the rush of air upwards results in a region of low barometric pressure. As these regions are formed, usually only on a large scale on our west coast, winds from the northeast and southwest rush into the low-pressure area, causing a vortex motion. In the northern hemisphere the winds circle around this area in a direction contrary to that of the hands of a clock if one is looking down on it. This region of low pressure is carried across the country by the prevailing westerly wind. From its travel one can thus predict with considerable accuracy the arrival of low pressure for any locality. This is the basis of our system of weather prediction.

Sometimes a cumulus cloud will become greatly overgrown and thus a cumulo-nimbus

cloud will be formed. This is how a thunder-cloud is made. A thunder-cloud is easily distinguishable from the ordinary cloud in that it has many sharp points projecting from it. It lacks the billowy appearance of the ordinary cumulus cloud.

Above the cumulus clouds we have the alto clouds. These are in general shaped like the cumulus clouds, but are smaller. Often, however, they obscure the whole sky and are then called alto-stratus. Again they form themselves into a distinctly wave-like form. This is usually at the boundary of two layers of air of different temperatures and velocities. While these clouds often form a thick veil of grayish or blue color, they are in general fair-weather clouds.

The highest clouds are the cirrus clouds. These are the feather-like wisps that one sees high up. They usually consist of ice-particles and are formed when the convection currents reach these high altitudes before condensation takes place. When these have extended so as to obscure the sky, rain is almost certain.

When a region of low pressure is approaching, the cirrus are the first clouds to appear. Since they are high up, they are less interfered with than are the other forms of clouds. Later a wind is likely to come from the southwest, and the cumulus clouds begin to appear. Rain will then follow. Often, however, the cirrus clouds may

never have formed, and local conditions may interfere with the winds.

Generally a wind from the south or thickening cirrus clouds promise rain. Since a wind circles around this low area in a counter-clockwise direction, the clearing may be accompanied by a veering of the wind to the north. A cloudy condition with a wind from the east indicates that the storm is south of us. A west wind indicates that it is north. In this way the weather can be predicted at least a few hours ahead by the amateur. The Weather Bureau, having simultaneous reports from all over the country, can map out the progress of a storm a few days ahead.

Hurricanes, cyclones and other violent atmospheric disturbances are caused by exactly the same things that cause the ordinary variations. They differ only in that, because of some unusual factors, they have more than the ordinary violence. A cyclone is similar to our ordinary low-pressure region, except that the winds circling around this area approach hurricane velocity, over seventy-five miles per hour. Cyclones usually breed in the tropics, however, or at some place where two currents of air meet which have considerable difference of temperature or moisture content.

V

MAN

Man Inherits the Earth

THERE are two schools of thought in regard to man's origin. There are those who hold that man has evolved from the lower forms of life which resemble man—the ape and his progenitors. On the other hand, there are those who hold that man has evolved separately from those forms along a distinct line; that there is no direct relation between the ape and man; that man has existed in a form resembling that of to-day since the beginning of our geologic record of about 400,000 years.

The reasons for the first view—that man is a direct descendant from some ape-like form—are obvious even to the layman. There is unquestionably a close resemblance between man and the ape, and upon careful study this resemblance becomes even greater. The difference is so slight as to fool the experts. Skulls recently found in Bechuanaland were at first labeled as those of apes and later relabeled by the ethnologists as those of men. The line of demarkation between early man and the ape is extremely slight.

Let us consider some of the evidence offered by the geologic record for the second point of view.

Going backward from our time, which we shall call the Recent Age, we reach the beginning of the Ice Age. The Ice Age, more correctly known as the Pleistocene Period, was not a period of continuous glaciation. It was a period of alternate hot and cold. There were, in fact, four ice periods, separated by much longer periods of higher temperature. Before this time was the Tertiary Age, the last division of which is called the Pliocene Period. This description follows the American nomenclature, which differs somewhat from that used in Europe.

Most of the animals which lived in America before the first glacial period are now extinct. Probably this is due to the severity of that period. Some, however, survived the extreme conditions. Horses, camels, and peccaries seem to be of this group. When the warm period came—the Aftonian—many animals came to America across Bering Straits, an overland route, as the continents were not then separated. This migration included such animals as elephants, lions, tigers, moose, deer, bears, dogs, and many smaller animals. Others are thought to have come in from South America—many strange forms which no longer exist, as well as those still characteristic of that continent. It is thought that fully one-third of the animals of that period are still to be found, the other two-

thirds having been wiped out by the succeeding three glacial periods.

Has the process of evolution changed these animals notably? Dr. Oliver P. Hay, of the Smithsonian Institution, writes:

"The numerous horses of the Aftonian became extinct, but some of them, as shown by their skulls and skeletons, differed from our domestic horses so little that the experts can hardly tell the difference. The abundant camels of that time have their counterpart in the camels of the old world and the llamas of South America. The elephants would be recognized as such by any child who had witnessed a street parade of a circus. It is evident, then, that evolution, which produces all natural changes in animal form, has effected little in the perhaps 400,000 years since the Aftonian stage. A learned writer on mammals tells me he doubts that a single new species has been developed since the first interglacial stage. The great changes in the animal life in this country have been due, little to evolution of new kinds of animals, but almost wholly to the extinction of the many especially large and striking forms."

Animals have changed little if at all in this long period. Now, what do we know in regard to man? The discussion here must center around the Neanderthal man, who appeared a little before the middle of the last glacial period. His

appearance can only be described as ape-like. He had the curved spine and walked in the stooped, bent-kneed position characteristic of the apes of the present day. His skull was flattened at the back, his jaw protruded into what might be called a muzzle, resemblant of the features of the lower mammals. His receding chin and forehead sloped back to such an extent as to be hardly worthy of the names. He had a broad flat nose and large eye-sockets. He was distinctly ape-like, but was he ape or man? He has been described, so far as appearance is concerned, as about three-fifths man and two-fifths ape. But let us see how he may be regarded.

First of all, the Neanderthal "man" may be considered as a link in the chain from ape to man. It has been argued that he is the direct progenitor of the Cro-Magnon race, which appeared during the latter half of the last glacial period, and which is easily recognized as belonging to the human race. That this could be true is doubtful. It requires that we believe that in the course of a few thousand years man underwent a far greater evolutionary change than have any of our animals in the entire period of about 400,000 years since the beginning of the Pleistocene Period. This is difficult to believe. Marcellin Boule, the French anthropologist, in his book, *Fossil Men,* writes, that this would be "a mutation so great and so sud-

den as to be altogether out of the question." It may also be pointed out that at this same time there lived in the same vicinity as the Neanderthal man a race which resembles very much our present negro. It is difficult to believe that such vast changes should have taken place in the Neanderthal man and left the progenitor of the negro, the Grimadi race, untouched.

We are left, then, with the alternative that man existed in the Tertiary Period, before the Ice Age, in much the same stage as he is found to-day in the uncivilized parts of the world; that he, like the animals, has evolved but little since that time, the degree of evolution being shown by the differences which now exist in the various races found in different parts of the world. This, of course, leaves us with several things unexplained. Why do we find no evidence of his existence during these early periods? How can we account for the sudden appearance and equally sudden disappearance of the Neanderthal man, and his immediate succession by the Cro-Magnons?

The problem is baffling and may never be solved. Nevertheless, scientists will keep on trying to find a clue to the mystery. It is detective work carried to the *n*th degree. Every part of the earth is being scoured for evidence. Expeditions are constantly searching the most out-of-the-way places, risking hardships, dangers, and

possible death in the jungles for a tiny scrap of evidence to piece out a solution of the mystery. Every scrap of possible evidence, when brought back to civilization, is weighed and reweighed, analyzed and discussed, to obtain from it every bit of meat that might be of value.

It is indeed unfortunate that these men, whose interest is only in the facts they find, and who are willing to change their views as each new scrap of evidence dictates, should be hampered in their work by interference on the part of those who are not fully informed as to the true purpose of the work, and should of necessity spend part of their time in fighting damaging legislation which prevents, in many places, a free discussion of their findings. That this is so is unquestionably due to a lack of public knowledge of the subject, and will doubtless be overcome by the wave of popular interest in science which has recently been aroused throughout the world. We may be sure that the work will be pushed to the limit of human ability and that almost any time startling discoveries may come out of the heart of Africa or from some other little-known region of the earth's surface.

The Horde Instinct in Man

In the matter of man's sexual matings and the origin of the present essentially monogamous social system, there are, as might be expected,

various theories. It was long the popular belief that the present system developed from a horde system which resembled that of the lower animals; but of late this thought has been largely abandoned, because no primitive tribe has been found in which such a custom prevails. True, there have been found tribes in which promiscuous relations are permitted in early youth, and others in which several matings may be made during a lifetime; but the social system is, nevertheless, in both cases essentially monogamous. The tie between male and female at least continues during the child-bearing and early rearing period. The behavior of these people may be described quite readily in terms of that of many of the people in the more civilized countries of the world to-day.

Another reason for our difference in social life from that of animals, that has been suggested, is that none of the animals have an ever-present mating instinct, as has man. The mating instinct in animals is dependent upon the seasons or upon some physiological change. Man, as has been supposed, is the only animal in which this is not the case. This, however, has been found to be untrue. The mating instinct has been found, by observation, to be the same in monkeys and apes as it is in man. It is neither seasonal nor dependent upon physiological changes, but is ever present. This is a conclusion reached by

no less an authority than Professor Robert M. Yerkes, of Yale University, who during the last fifteen years has conducted a series of brilliant experiments on the habits of these animals. He has found that the mating instinct is ever present in them. Unfortunately, his findings have been largely overlooked by anthropologists.

If this social factor, ever-present mating, is the cause of our monogamous system, then evidence of at least the rudiments of a similar system should be expected in the life of monkeys and apes. Such is not the case. The monkeys are found to live in hordes and to follow the horde system of sexual relations. There is no evidence of monogamy. There is nothing resembling the family ties of the human race.

That the horde instinct is present in man is everywhere in evidence. One does not need to present a statistical study of violations of accepted social behavior to prove this point. It will be readily accepted. Not only are violations of what is considered proper social behavior common, but it goes without saying that there are many who are held in check only through the fear of social ostracism if the misbehavior is found out. If, overnight, all of our social taboos could be swept away, there is little doubt that the outcome would certainly tend strongly toward a horde system. The fact that the Great War did in reality sweep away many of these

traditions at one time constituted a real menace to our social system. The fact in itself, that most of our social taboos are obviously intended to check the horde instinct, is evidence that a real danger to society exists in this possibility.

The reasons given by Dr. Gerritt S. Miller, Jr., curator of Mammals of the Smithsonian Institution, for the development of our present social system are, first, the human ability to form enduring association between partners and thus make sex-love a socially effective force; second, the fact that only in the human race can the female be forced by the male; and last of all, man's property sense, only the merest rudiments of which are found in any of the animals. "All of these facts seem to justify the tentative conclusion that those of our customs which center about the family are best explained as a modified horde life not yet completely adjusted to civilization's needs," says Dr. Miller. "When the process of change began we do not know, but it was doubtless at a time so remote that no present-day race of men had come into existence. The breaking up of the old horde may be conceived to have taken place under the influence of the specially human characteristics of mating psychology, which have just been mentioned, combined with and directed by man's rapidly growing property sense."

The Origin of Speech

It is difficult to conjecture as to the origin of speech, but one possibility that deserves consideration is that speech arose from pantomime with the lips and tongue. The idea is far from new, and appears to have been suggested by Socrates. An extended paper along this line of thought was presented before the Royal Institution by Dr. J. Rae as long ago as 1862. Later the idea was fostered by Charles Darwin, and as well by his noted rival, Alfred Russel Wallace. Recently this possibility of the development of language has been given much study by the English scientist, Sir Richard Paget. He has pointed out that emotion in the insect world is commonly expressed by sound, as in the love songs of crickets and birds. Pantomime is also used by birds and insects to convey ideas. Bees inform their colleagues of good finds by the honey and pollen dances which were first observed by Professor von Frisch of Munich. Warblers and the crested grebe present samples of nesting material as a courtship gesture.

Sir Richard Paget has pointed out that in archaic Chinese, in ancient Sumerian (as spoken at Ur of the Chaldees), in the Aryan and Semitic languages, and even in Polynesia and the west coast of North America, the same root words occurred—made by the same descriptive tongue

gesture—as, for example, the upward movement of the tongue which produces the word "al," meaning high, strong, protect, or rise. In support of his contention Sir Richard Paget has also pointed out that the descriptive words formed by children when they attempt to explain something for which they do not know the usual words, follow this rule. He also points out that the greater use of the hands in talking by the southern over the northern races is due to the fact that the northerners lived a harder life. They worked more with their hands and thus had them less free to use in descriptive pantomime. They were compelled to make their gestures with the mouth and tongue. Such gestures would, of course, be accompanied by a grunt to attract attention, and the sound of this would be influenced by the position of mouth and tongue and would in time be recognized, without visual observation, by the person addressed. To support the contention that all vocal sound is merely made by grunts modified by mouth and tongue positions, Sir Richard Paget has presented to skeptics an artificial vocal apparatus. A vibrating reed produces the grunts, always the same, and these are modified into understandable words by manipulation of the parts corresponding to mouth and tongue. His theory is well supported and somewhat convincing.

Why We Behave Like Human Beings

Why we behave like human beings is a problem over which the psychologists have long wrangled. What is it that makes any of us behave as we do? Are our acts predetermined before we are born? Are our destinies governed purely by external circumstances over which we have no control? Are we in any sense masters of our fate?

It is obvious that there are many answers to the questions asked. There are many possible viewpoints. Noted psychologists have taken the stand for one or the other of these possibilities and have defended them against all others; they have insisted that one or the other was the important factor. A more sensible viewpoint, however, must be that each and all of these are important; that one may, of course, be more important than another; and which one may be the most important must of necessity differ with the individual under consideration.

When one has read the section of this book dealing with heredity and environment, much will be clear without further comment. The method whereby nature transmits individual characteristics through the chromosomes makes it a foregone conclusion that, except in the case of relatively rare mutations, the nature of the offspring must be a composite of the character-

istics of the parents. Its traits must be those traits which have previously existed. Thus it is that mental capacity, predisposition to crime, musical talent, and all the characteristics that one could possibly think of, are definite things which are transmissible. It cannot be denied that, under the same set of conditions, two individuals, one with musical ability and the other without, would possibly react very differently. All beings are not born free and equal. Different talents must determine different behavior, regardless of environment and other determining factors.

The second great factor in behavior is environment. This factor includes a wide range of things. It includes companions, food, opportunity for education and the development of special talents. That food is an important factor in the progress and the behavior of an individual there is much evidence to verify. That the influence of parents, companions, etc., is strong likewise cannot be denied. The inclination to imitate the action of others, so common in children, is evidence of this. Education is likewise of recognized importance, and other factors are, in general, also effective.

But all of these things are not enough to account for all individual behavior. Persons well endowed are often found in the ranks of human failures. There is something which must come

from within. Possibly what comes from within merely reflects what is without, as many contend. Nevertheless, there are those human complexes which are difficult to classify as due to anything other than the action of that particular brain.

"In earliest childhood," says Dr. Alfred Adler, "our physical inequality results in a normal feeling of inferiority, which reappears at intervals throughout life as we face each new series of difficulties. It is the motivating cause behind all constructive action.

"To counterbalance this feeling of inferiority the child early invents a goal of superiority, a way in which he strives to excel," says this authority. "Just as his body develops towards its final physical form, so his mind creates an ideal final form toward which every effort, thought, and movement tends, consciously or unconsciously, and despite every obstacle.

"To know the goal the mind has selected is to understand at a single leap the whole network of thought and action which is the 'behavior pattern' of the individual."

Behavior patterns are formed within and not without the individual, for this great psychologist adds:

"The only true and adequate compensation for our normal feeling of inferiority is the consciousness that we are part of all humanity and

of its accomplishments. It is this sense which makes for great achievement, useful and happy lives. No one can determine for another the direction in which he will walk, but the child can be helped to understand the choice he has to make and to choose the goal of superiority which fits into the social scheme."

It is obvious that failure to make the proper adjustment to our social conditions is the cause of many if not all of our so-called human failures. A child may be endowed with every opportunity which would lead him to the correct attitude, but failure to arrive at it would be fatal.

The subject of human behavior is an important and interesting one for us to-day. Failure to solve and control its causes is resulting in an ever-increasing drain on civilization. The criminal and the insane are unquestionably on the increase. The problem demands the united efforts of the best brains the world is capable of mustering.

Man's Changing Social Life

That social habits are reflected in our occupations there can be no doubt. A nation is an agricultural nation if a large proportion of its inhabitants are farmers; it is a manufacturing nation if a large percentage of its people are engaged in factory work. Professor W. F. Ogburn,

using this basis of analysis of the social trend, has but recently published some interesting data in the book, *Social Changes in 1928,* which has been printed by the University of Chicago. The number engaged in the silk industry is increasing more rapidly than the number in the cotton industry. The white-collar class is increasing more rapidly than the labor class. Domestic servants are decreasing, while waiters are increasing. Dentists have increased four times as fast as the population since 1850. In the same period plumbers, steam and gas fitters have increased 11,000 per cent. Barbers, hairdressers and manicurists have increased eight times as fast as the population. Chauffeurs and candy-makers are rapidly increasing. Social and welfare workers increased from 16,000 in 1910 to 41,000 in 1920.

From 1900 to 1920 the total population increased 39 per cent. and the urban population 49 per cent.; yet the number of waiters increased 113 per cent., and during the latter part of the period the number of restaurant-keepers increased 158 per cent. Delicatessen dealers have increased about three times as fast as the population since 1910, and employees engaged in canning and preserving fruits increased 37 per cent. in the period 1914 to 1925, despite the increased use of machinery.

It is not a difficult matter to draw conclusions

from such statistics. One of these, which cannot be controverted, is that our family life is changing rapidly. The increase in canners, waiters, restaurants, and so on, indicates clearly that the nature of the home is undergoing a revolution. Its old occupations are disappearing. Our standards of living are likewise changing. This is reflected in the increase of those in the luxury occupations—chauffeurs, candy-makers, hairdressers, and plumbers.

It is evident that our amusements are likewise being taken out of the home. They are being commercialized. In other ways the family life is disappearing. Many of the functions of the family are being taken over by the state.

Many further deductions could, of course, be drawn from these and similar data. Many of them would doubtless be debatable. We leave such deductions to the reader; likewise the question whether or not such changes are desirable. The subject holds much of interest to the thoughtful.

Final Earth Population

One of the favorite topics of discussion in the study of man's possible future is the speculation as to when the earth will have as many inhabitants as it can hold and what will happen after that limit is reached. It is not the purpose of the author to speculate upon the question

here; but an outline of the factors affecting such calculations cannot be out of place.

Those who have studied this subject necessarily take the possible production of food as a basis of estimate. The earth cannot hold more individuals than it can provide food for. In the past this food production has been based upon the known acres of land under cultivation and the number necessary to support a human being. Allowance has frequently been made for increase in agricultural efficiency. In the past such an allowance has, for the most part, been greatly underestimated. No one foresaw, at the beginning of the twentieth century, the increased agricultural efficiency of to-day. It is fair to presume that the same would be true of present predictions. Nor has the possible farming of the ocean (five-sevenths of the earth's surface is under water) been given reasonable consideration. These are all factors which cannot be intelligently estimated.

The decreasing birthrate is likewise a factor of great importance. It may keep us well away from any approach to saturation numbers. A study made by the Department of Economics of the Brockings Institution in Washington, which covered Great Britain and Ireland, France, Belgium, Holland, Switzerland, Germany, Denmark, Norway, Sweden, and Finland, together comprising over ten per cent. of the earth's

population, indicated that already the population is not only failing to increase but has a virtual deficit of about seven per cent. If this were true generally, saturation conditions would never be reached. But it is not. There is an increase of about five-eighths of one per cent. a year over the entire world. "If this rate were to persist, there would be a doubling of population in 110 years," says Professor Robert R. Kuczinski, of the Berlin Handelshochschule. "At present the total of human beings on the face of the globe is somewhere between 1,700,000,000 and 1,900,000,000. But the earth's capacity is limited by the potential agricultural resources, and, assuming that there are 15,000,000,000 acres of arable land and that 1.5 acres on the average are sufficient to support an individual, the maximum population would have to be placed at less than 10,000,000,000. Even allowing for all conceivable advances in technique, and assuming that all human effort will be directed to the maintenance of a maximum number of people, it seems impossible that the earth could sustain more than six times its present population, or about 12,000,000,000 people." Such is the view of an expert who has given much study to the subject.

VI

THE FIGHT FOR LIFE

The Battle Against Disease

THE struggle against disease is won. Most of the advance which medicine will make in the future will be against old-age ailments. We no longer think that germs originate in dirt and filth. The germs must get there from some one affected by the disease. We no longer think that germs are carried in the air. We do not cross the street in passing a house isolated because of some communicable disease. We know where to look for troublesome bacteria. Since Pasteur, in 1877, first demonstrated the existence of living bacteria in the case of anthrax, most of the disease bacteria have been identified. The situation cannot be better summed up than in the words which Colonel H. V. Wurdeman used in a radio address:

"Our whisky has been mostly taken away from us, diabetes is cured by insulin, syphilis by salvarsan; tuberculosis, typhoid, diphtheria, by inoculation and serums; smallpox by vaccination. Even the common cold, the forerunner of many deadly diseases, is amenable to serum treatment. The people generally know these facts and seek early treatment. Sweeping epidemics

of smallpox used to take off ten per cent. of our ancestors. Now no one should die from it; in fact, no one can take it if properly vaccinated. In my early practise 50 per cent. of children with diphtheria died, now only six per cent. There should be no more typhoid or other such diseases as were common up to twenty-five years of age. We know the menace of the house-fly, the flea, and the louse."

With this summary of present conditions, what may we expect of the future? The bacteriologist has been with us for some time, and he has accomplished much. Latest developments indicate that the time for assistance by the physicist and the chemist has arrived. The increasing use of the x-ray and of radium in the treatment of cancer is one application of the tools of the physicist. In addition we also find important research under way to determine the value of short radio-wave treatment. High-frequency oscillations between 60,000,000 and 70,000,000 cycles per second have been found effective in reducing tumors in rats. The new and powerful cathode-ray tube gives promise of a development which will make it the equivalent of tons of precious radium. The therapeutic use of ultra-violet radiation has become so general in the last few years as to be considered almost a fad.

The chemist is likewise making valuable con-

tributions. Not long ago, if a medicine cured it was considered satisfactory. Now the chemist wants to know just what it is in the medicine which cures. No sooner was the beneficial element in the irradiation of certain foods suspected than the chemists isolated it. It is ergosterol, a substance so potent that a piece much smaller than a pinhead per day is enough to prevent rickets. It is more potent than a pound or two of cod-liver oil.

Dr. William J. Mayo, speaking before the American Chemical Society recently, said: "Day by day a new conception of medicine brings forth basic facts which enable us to look on man as a chemical unit as capable of analysis as material in the test-tube. The study of vitamins, of hormones, of endocrines, and the electric concept of the nervous system are but a few of the outstanding investigations which are too recent for analysis." In closing his remarks Dr. Mayo further said: "Life is largely a matter of chemistry. The advancement of medical science began with those things which could be seen with the eye, the eye aided by a microscope, and has now progressed into the ultramicroscopic field of chemistry. In its modern conception, therefore, medicine has become a branch of applied chemistry." We are well on the way toward a complete defeat of disease.

Rejuvenation and Revival of the Dead

Along with the notable advances that have been made in medical treatment have gone equally notable gains in surgical practise. We may now say that almost the entire human body is subject to surgical treatment; almost every part may be reached by the surgeon's knife.

This being the case, it would appear that there was little advance to be looked for in this field of science. Such is not the case; the advance here has been as notable in the last few years as in any field of medical practise. This has been largely due to the adoption of new methods from the biochemical and physical fields. The introduction into surgery of the new electro-surgical units, which might be called electrical knives, has done much to alter and to refine the technique of the surgeon. In particular this device has proved its value in operating on certain forms of brain tumor, greatly simplifying the procedure. There can be no doubt that there will be a rapid extension of the use of this new instrument, which may in effect revolutionize surgical practise, even tho it does not extend the surgeon's field.

Recently medical treatment has taken over some of those things formerly wholly treated surgically. But since the reverse is also true, the surgeon has maintained his ground. One of the

transfers of the first-named class has been in the treatment of pernicious anemia. The frequent transfusions of former days have been superseded by the liver diet. But while this would appear to be a loss to surgery, we have the counterbalancing fact that diabetes is no longer a handicap to the patient requiring surgical aid. It has also been found that Raynaud's disease and Buerger's disease, once thought to be entirely in the field of medical treatment, are subject as well to certain surgical aids.

The manner in which the physicist can be of aid to the surgeon is well illustrated by the introduction of the artificial voice-box. In cancer operations which require the removal of the larynx, the patient in the past has been condemned to silence for the remainder of his life. Removal of the larynx means removal of an essential part of the voice mechanism. Now an artificial larynx can be used and the patient can speak clearly and loudly. It is even possible for such an individual to address successfully a large audience.

The cause of cancer has long baffled medical science, and altho some unanimity of opinion regarding its cause seems gradually being arrived at, no form of medical treatment has as yet been found. The field of cancer cure is left to the surgeon and to treatment by x-rays and radium. Of these methods, that of the surgeon

seems at the present time to hold the major place. If taken in time, this method has proved successful.

Every now and then we note in the press some reference to a startling achievement of surgical science. We read of rejuvenation by surgical operation, or even of revival of the dead. What is there to these startling claims? Have they any basis in fact? The answer must be of the "yes and no" variety. Let us see.

The human body does not wear out all at once, cease to function, and collapse. Certain vital parts may cease to function; the other parts may still be quite capable of carrying on their duties. Suppose, for example, the heart stops beating. We are really no more dead from this than we would be if an arm suddenly became paralyzed. It is not because the heart stops that we die, but because it causes death of the other organs by its failure to function. The paralyzed arm would not have done this. If the heart-beat can be stimulated again before death of the other organs actually occurs, then they willingly continue to function. This can often be brought about in an otherwise dead person by the injection of a heart stimulant. Adrenalin is often used for this purpose. Not many years ago such a person would have been pronounced dead; now, if the heart can be stimulated to action and the

cause of its stopping removed, he may live again for many years.

Likewise surgery now offers the possibility of the substitution of a more reliable heart. This does not appear to be possible by the substitution of an animal heart for a human—a process which was at one time much before the public eye as a possible rejuvenation method, but which has failed. The blood at once sets up a reaction against the introduction of foreign cells, even when they come from the same species. The result is that while they function for a short time they soon sicken and die. It would appear that if we are to make substitutions they must be like the larynx referred to above, not mere transfers of an organ of one body into another; artificial organs must be used. As a matter of fact, artificial hearts have been made and have functioned successfully over long periods of time. Dr. O. S. Gibbs, of Dalhousie University, has been able to place rubber hearts in cats by surgical operation. These hearts are in the nature of rubber pumps, and their sole function is to keep the blood in motion, apparently all that is necessary for a heart to do.

Whether or not such hearts shall ever be used in human beings to replace defective ones is a matter of speculation outside the field of this book. It would appear, however, that an individual afflicted with heart trouble and know-

ing that his heart may cease to function at any moment might be willing to use such a device to prolong his years.

Interesting experimental work has been done in the revival of such organs as the kidney, liver, heart, and even the brain, after removal from the body by operation, all of which may eventually contribute immeasurably to the possibilities of surgery. Chief among the workers in this fascinating field are Professor Feodor Andrievitch Andrieve, a Russian scientist, and his assistant, Dr. S. S. Brunkhanenko. The latter has actually been able to keep alive the head of a dog severed from the animal and supplied with artificial blood from an artificial heart. For three hours the head of the dog is reported to have had every indication of life. It swallowed cheese, rejected acids, and moved its eyes. This is no more surprizing than the jerk of a severed frog's leg when touched by a high voltage wire. The nerves are still capable of reaction even tho the rest of the animal is dead.

But just what does this mean to the surgeon? It does not mean, of course, that he can completely disassemble a patient and leave the parts lying around until he gets ready to put them together again, as a garage mechanic would treat an automobile. It does, however, offer the possibility of substitution of parts, just as a voice-box may be substituted for a larnyx, as a man's

skull may be replaced by a platinum one, and so on. It also offers the eventual possibility that parts may be temporarily removed for close observation. Surgery is in an interesting state of development.

Ultra-Violet Light

Probably there has been no more important development in medicine of recent years than the introduction, study, and use of the ultra-violet. No sooner were its beneficial effects in the case of rickets discovered than its effects on the system in general were determined, the results of eating food radiated with this ray investigated, and finally the exact chemical substance in the food responsible for this effect isolated. Ultra-violet has become a fad almost overnight.

There are those who question the advisability of the use of an unknown tool of this sort to such a wide extent without its having been tested by time. They point out the ill effects which attended the early use of the x-ray by physicians who had no knowledge of its dangers. On the other hand, we are reminded that there is nothing in the ultra-violet light which is not present to some degree in ordinary sunlight. This cannot be said of the x-ray. But why, they ask, take healthy individuals and subject them to a ray the intensity of which has not previ-

ously been applied to man? The fact is that while the intensity is large it is never used over long periods of time. The likelihood is that man, in his primitive state, was subjected to much greater exposures. With our artificial modes of life, our clothes, our buildings, and our smoky cities, this health source has, for most of us, been largely cut off. We must take our supply in short, intense doses. When not taken in excess, it is the general opinion of the medical profession that these treatments are decidedly beneficial.

To quote the eminent English authority, Professor Leonard Hill, M. B., F. R. S.: "Mist, smoke, pollution, glass windows, walls and roofs and clothes cut out the sunlight and deprive us of the effect which the sun naturally exerts on naked wild men and animals—for example, on ergosterol, which, eaten in the food, is present in the skin, and there awaits activation into vitamin D by sunlight." After pointing out the value of these rays in the prevention of rickets, along with which goes decay of teeth, liability to catarrhal and low infections, and so on, he further sums up the value of actinotherapy as follows:

"The damage of the living cells in the skin produced by sunburn provokes secondarily a local hyperemia, œdema and leucocytosis, followed by desquamation and pigmentation. The

inflammatory reaction increases the power of the blood to kill staphylococci as tested in vitro. In some way, as yet unexplained, it provokes a better feeling of health and vigor, but overdosage may have the opposite effect. The inflammatory reaction helps the skin to recover from infections such as lupus. This terrible disease is cured by local and general light baths. Surgical tuberculosis is benefited by light and open air."

But it is no longer necessary to eat food containing ergosterol and wait for its activation into vitamin D by sunlight. The food itself, or even the extracted ergosterol, can be activated directly by ultra-violet light and then taken into the system. This material is so potent that a mere speck of it taken each day is sufficient to prevent rickets. A speck is as potent as a few pounds of cod-liver oil. Irradiated foods, sunshine pills, and so on, are becoming the vogue, and there appears to be little if any evidence that the effect on the system is anything but beneficial.

VII

MAKING MAN TO ORDER

The Riddle of Heredity

"THERE'S a divinity that shapes our ends, rough-hew them how we will," states only part of the truth. There is certainly a power which is mostly responsible for shaping our ends, but which nevertheless can be somewhat influenced by the rough-hewing process. This is the equivalent of saying that we are subject to two forces —heredity and environment. A knowledge of the manner and degree in which both of these factors are operative is of the utmost importance to man.

Let us first consider heredity and see with what facts science has been able to present us. Heredity follows a single great law, upon which all our knowledge of the subject is based. This law, known as the Mendelian Law, was discovered by an Austrian monk, Gregor Johann Mendel, in 1865, as the result of his observations on sweet peas. It is applicable to all animal and plant life. It is interesting to note that, published in an obscure journal, it lay buried, unknown by the world's scientists, until 1900. During that interval they were largely groping in the dark.

This law recognizes in each individual's make-up both dominant and recessive characteristics; the color black, for instance, is dominant over red in Aberdeen Angus cattle. The law can best be described by an example. Let us assume that two people mate, the one having blue eyes and the other brown; the brown eyes being a dominant factor and the blue eyes recessive. Then, according to the Mendelian law, the offspring will have brown eyes, the dominant characteristic. At the same time, however, this person will possess the ability to transmit either of these characteristics to his or her offspring. It will be found that three-quarters of the offspring of this second generation will have the dominant characteristic, brown eyes, and the remaining quarter will have blue eyes.

Now, what may we expect to find in the offspring of the third generation? If two of these members, showing the recessive characteristic, are bred together, the subsequent generations will carry this hereditary factor, blue eyes, constantly. If those members of this generation which show the dominant characteristic are observed, it will be found that one-third of them produce purely dominant offspring, while the remaining two-thirds will go on producing the same proportion of recessive, pure dominant, and hybrids that were produced by the third generation.

Thus, if we know the dominant from the recessive characteristics, we can predict the results of any mating. We know that the offspring of the first generation will have only the dominant characteristics. We know that the second generation will be three-quarters dominant and one-quarter recessive. We know that the next generation will be divided so that one-third of them are capable of transmitting the recessive characteristic only, that one-third of the remainder will be capable of transmitting the dominant factor only, and that the remainder will have the same powers as had their parents; their offspring will be divided just as was the parents' offspring. The importance of the knowledge of this law to humanity can hardly be overestimated. It is essential to any intelligent approach to a solution of the riddle of heredity. The study of heredity is reduced to a scientific basis.

Blue-Prints for the Next Generation

But science has gone farther than this. It has been satisfied with nothing less than knowing how these heredity factors are transmitted. It has gone into the germ cells themselves and has discovered exactly what it is in these cells which is responsible for hereditary transmission. In all plant and animal life it has been found that the reproduction cells contain a number of small microscopic rod-like bodies. These are called

chromosomes. The number of these chromosomes in any particular cell depends upon the plant or animal to which it belongs. In general it can be stated that for any particular species the number is always the same, but to this there are many exceptions. In some cases the number is quite variable. In man the number of chromosomes is always twenty-four.

When a mating takes place, each of the fertilized cells will again contain twenty-four chromosomes. Half of these will have been contributed by the male and half by the female. Thus it is not possible that the offspring may partake wholly or in major part of the characteristics of the one or the other of its parents. It must partake of the characteristics of each. Nor should it be imagined, if this is true, that brothers should have characteristics necessarily alike. There are an enormous number of ways in which chance might select twelve each out of two groups of twenty-four things. That two brothers should be born of selections of the same identical chromosomes from each parent is possible, but they would so closely resemble each other as to make it difficult if not impossible to distinguish the one from the other. This is the case of identical or one-egg twins. Such twins are the result of the splitting of an egg after fertilization, and the individuals should therefore have the same group of chromosomes. That they are as like as

two machines made in a factory from the same blue-prints is evident to any one who has known such individuals before the factor of environment has entered in to affect the one or the other noticeably.

Some striking work in this field has been done by Dr. Arthur M. Banta, of the Carnegie Institution of Washington. He has made an exhaustive study of water fleas. These animals, like a few other forms of life, have the ability to produce young without the necessity of the egg being fertilized by the male. Dr. Banta has studied nearly nine hundred generations of these fleas, all produced from their parents without egg fertilization. Each generation can have only the same set of chromosomes. In all this time no new chromosomes have been introduced. The last member of this long line of descent has the same kind of chromosomes as the first. Throughout, each member of this family has been as much like all the others as identical twins, daughter like mother, grandmother, great-grandmother, and so on.

But an individual has more characteristics than can be represented by twenty-four chromosomes. It is obvious that these bodies must each have wrapped up in it the possibility of transmitting, in whole, a large number of characteristics. Each factor contained in the chromosome is called a gene and is thought to consist of a

bundle of atoms or molecules. With each gene some particular trait is identified, but to the present time it has been found next to impossible to associate particular traits definitely with particular genes. In a few cases of plants, where chromosomes with similar ends have been found in two varieties, identification or rather localization of the gene has been possible. In this case the fact that both varieties possess one gene in common makes it probable that the characteristic associated with that gene should occur twice as often. This can, of course, be observed.

When it is possible to associate these characteristics with particular parts of the chromosomes, the possibility of making an individual to order is evident. To do such a thing in practise, however, is far outside the probable. Certainly in the higher forms of life it is impossible to imagine that it can ever be done.

Speeding Up Evolution

But certain and definite tho the foregoing exposition of the process of heredity may seem, it is, in fact, far from it. Nature has a way of occasionally completely fooling us, leaving us quite baffled. Every once in a while, not often, something goes wrong; an entirely new and previously unknown trait is introduced. There may be no trace of criminal traits in the entire family tree of either parent, and yet a criminal

is produced. Perhaps, in the other direction, those of a low degree of intelligence may produce a genius. In Dr. Banta's water fleas, with no opportunity of a change in a chromosome pattern, there was suddenly produced an individual with a different shaped head which persisted in the succeeding generations. When such a thing happens under observation it is of the utmost importance to science. We are witnessing evolution at work. Such a change is called a mutation.

When a mutation occurs it may be for the good or the harm of the race. It may produce an individual more or less adaptable to its environment. In the latter case the individuals are better able to cope with hardships than are the other members of the race, and this group will persist while their less fortunate brothers will perish. For one useful mutation it is probable that a hundred or more useless ones will likewise have taken place.

Just what causes these mutations is still a decided mystery. We can only guess. Evidence, which directs our guess somewhat, suggests that it must be due to some rearrangement of the molecules or of the atoms, or even a change in the internal structure of the atoms themselves. This latter suggestion seems at present to be the most likely of the three. It is based upon

the recent work of scientists in which they have been able to produce mutations at will.

This exceptional feat has been found possible by irradiation of the sex cells of both plants and animals with either x-rays or radium. In this way animals or plants can be produced at will which possess characteristics wholly different—different in a marked degree—from those of either parent. In this way evolution can be speeded up. But one should not anticipate that we can in great measure improve animal life at will and immediately. As has already been said, but few mutations are useful mutations. In general the method may be said to produce monsters.

That the mutations produced in this way are due to a change in the internal structure of the atoms themselves we have grounds for believing. In the study of the structure of matter by physicists the x-ray is used for the very purpose of altering the atomic structure; and it never fails. If the biologist is ever to study the modification of cells by this method with anything like the detail that physicists have used, he is up against a much more difficult problem. He has the ever-present difficulty of avoiding killing the cell, an obstacle to exact measurement which the physicist does not encounter.

Effect of Environment

Whether heredity or environment is the stronger factor has often been debated. Both are of great importance. In thinking of environment we must, of course, think of it as operating over a long period of time, for generations. In this case its significance is obvious.

Dr. Arthur M. Banta has studied this factor in water fleas under various conditions. These insects, under favorable summer conditions, produce only female offspring. In the fall, however, when the waters of the ponds recede and food becomes scarce, males are produced. Experimenting in the laboratory, he has found that the proportion of males to females can be varied at will by controlling the conditions. He has found that such factors as crowding, food shortage, and so on, have the effect of producing males. The fertilized eggs are hardier and more capable of withstanding adverse conditions and consequently are to be preferred for the perpetuation of the race. Cold, drugs, anything that tends to reduce the metabolism of the female, will produce a predominance of male offspring.

The relation between environment and heredity is clearly shown in goitrous families. The susceptibility to this disease is a heredity factor, but the disease will not be brought out except by factors of environment. It will be brought

out by a deficiency of iodine in the diet. Goitrous families living in the Great Lakes Region, where the water does not contain iodine, have always suffered from this disease. It was not until this cause was determined that much could be done for them. Now the disease can be prevented by supplying the missing environmental factor in other ways. It is frequently added to the diet in the form of iodized salt.

A certain kind of idiocy, known as cretinism, is likewise an environmental problem. It has been found to be due to inactivity of one of the glands, the thyroid. Feeding a cretinous child the extract from the thyroid gland of an ox has been known to restore it to a normal condition. This single environmental factor is extremely important. No less so is any factor affecting another gland, the pituitary. The pituitary gland, situated at the base of the brain, produces the hormone, a chemical substance, which is responsible for the development of an animal to maturity. Taking this hormone from mature rats and injecting it into infant rats, they become mature in eight or ten days. Hormones are largely responsible for the growth, development, capacity, and health of the individual.

Dr. John Munroe, of Long Island University, has made extensive tests over a number of years of the effect of food on the mentality of school

children. He has shown conclusively that this is a major factor. He has found that in poor families an increase in the number of children results in a decreasing mental capacity in the younger ones. As family circumstances become more straitened, and the food poorer, the children do not develop mentally. In families of means, he finds, the younger children are as bright as the older. He has also carried on feeding tests with brothers and has been able to obtain definite results in a great number of cases.

You cannot make a fast animal from a plow horse merely by stabling him with thoroughbreds, feeding him the same way, and in general giving him the same treatment. He will never equal the pace set by his stable companions. He will probably become, however, much faster than other plow horses.

Control of Sex

Can we control sex? That is always a question that parents wish answered. They would like to know that a boy or a girl, as the case may be, could be assured to them. Unfortunately for their hopes, science cannot as yet give them any comfort. Sex can be controlled, or even transformed, in some animals and birds, but in man —not yet.

The sex of the individual that will be born

of a particular egg fertilization depends either upon the kind of egg fertilized or upon the kind of sperm cell which fertilizes it. In some cases there are two kinds of eggs and one kind of sperm cell, as in some birds; or as in the case of man, there may be two kinds of sperm cell and but one kind of egg. When thousands of each kind of sperm cell are produced at each union of male and female, it is obvious that whether a male or female is produced is entirely a matter of chance. The only hope of sex control here would be in the possibility of separating out the particular sperm cell to do the fertilizing. Such a chance is very remote.

In the case of frogs and birds, which produce their eggs in a convenient form for experimentation, much has been done. It has been found that an egg which would produce a female frog if developed can be made to produce a male frog by making it undergo early development at high temperatures. If low temperatures are used the reverse will be the case. Males may also be produced by allowing the eggs to become overripe before fertilization.

In pigeons it is possible to produce only males by suitable mating. If two entirely different species of pigeon are mated, only males will be produced. This, in the human race, would correspond to mating a human with an animal as

different from it as the gorilla. It is not a likely or desirable method, so far as humanity is concerned. Yet, while in general it is not possible to predetermine the sex of a bird, it is often possible to change the sex after the animal has been born. Female chickens have always a good left ovary and a minute and disappearing right ovary. Now, it has been found that if the good ovary on the left is removed, the right ovary begins to develop. But it develops in a remarkable and unexpected way. It turns around and becomes, not an ovary, but a testis. The whole sexual apparatus then develops into the male system, and the bird, formerly a female, becomes a male and functions in its adult stage as a male. Other methods of accomplishing this apparent miracle are also known.

It has been observed that whatever tends to produce males is accompanied by an increase in the metabolic rate, and whatever tends to produce females by a decrease in this rate. This has led to the metabolic theory of sex; the suggestion that the rate at which the life process goes on is the sex determiner. According to this theory sex might be ultimately controlled by controlling this one factor. And here we seem to have the most hopeful of the methods which might eventually prove applicable to human beings. It would appear that control of metabolism might be affected by such things as temperature,

air supply, and so on. Thus it may be possible, in some measure, to control sex.

That there are at the present time border cases amongst humans is well known to all. These unfortunate individuals do not have their sex definitely determined. Many would welcome any treatment which might in any way tend to fix their sex characteristics. Biologists working on this problem constantly receive communications from these unfortunates. Perhaps some day their problems may be met, but at present it cannot be said that such a consummation is in sight.

VIII

THE STRUCTURE OF MATTER

Molecules and Atoms

UNDOUBTEDLY one of the hardest nuts to crack, for the beginner in modern physics, is the true conception of the molecular structure of matter. It is difficult to conceive the enormous number of minute molecules in even the smallest obtainable particle that the eye can see, even under a powerful microscope, and to imagine the velocities with which these particles are constantly moving about and hurtling against each other. The idea is not a new one. It is as old as civilization. Certainly the early Greeks had formulated a theory of matter similar to this. Democritus and his school, in fact, expressed the modern theory almost exactly as we know it to-day. Then, however, all was mere speculation. Science was a philosophy and was subjected neither to experimental test nor to the keen mathematical analysis that we know in this age. He who said that matter was continuous, therefore, had an equal right to be heard. We can now be certain that matter is discontinuous; that the distance between particles is in general many times the diameter of the particles themselves. To see them with the eye shall ever be denied us. No

instrument we may ever expect to develop will avail us anything. We are limited by the nature of the eye itself. But there are other kinds of evidence more reliable than sight which give us our knowledge—evidence which is quite unimpeachable. Thus we know that while a board, a bit of steel, or some liquid does not present visible holes, they are there, nevertheless. There is far more hole than board, or steel, or liquid. At a distance a forest appears to be a solid mass of leaves. On close approach the leaves are found to be quite far apart. The same would be true of any material if we could reduce ourselves to a corresponding dimension and at the same time have our eyesight suitably modified.

Stranger even than the granular theory of matter, is the fact that the individual particles are moving about with great velocity. Because of the numerous bumps with other particles, they never get very far. Accordingly the motion can best be described as a shivering. Hydrogen molecules, which move with the greatest velocity of all because of their lightness, actually travel at the enormous speed of about a mile a second under normal conditions of temperature and pressure. Two other familiar gases, oxygen and nitrogen, being heavier than hydrogen, travel at about one-fourth that rate.

If we were to examine a few molecules of various materials picked up at random, we

should find that they in turn were subdivided. They might have two, three, four or almost any number of parts. These pieces, next in size to the molecule itself, are called atoms. Modern science assures us that there are in all but ninety-two of these atoms, or there are but ninety-two elements. Of various combinations of these all our familiar materials are composed. These are the tools of the chemist. It is with them that he has his chief concern. Up almost to the beginning of the present century, atoms were supposed to be the smallest particles of matter, and indivisible.

Take, for example, a particle of common salt. If we examine one of its molecules, we find that it is made up of two atoms. One of these will be found to be an atom of the element chlorine, which by itself would be an ill-smelling greenish-yellow gas heavier than air. The other atom, sodium, is a metal, which, if placed upon water, burns with a great sputtering. No one would for a moment dream of inhaling the gas nor of eating the metal. Yet combined as salt they are palatable enough. It is worthy of note that these atoms know just how they wish to combine. If a chemist uses more sodium than is necessary for a one-to-one combination of atoms, there will be just that amount left over after the chemical reaction has taken place. In other

cases a two-to-one combination is needed, or a three- or four-to-one.

Man Probes the Atom

The discovery of the x-ray did many other things than make it possible to mend broken bones or dig bullets out of doughboys. It gave us a new tool with which to probe inside the atom. It was early observed that the air in the neighborhood of an x-ray tube became electrically charged. This was at first decidedly baffling. Did the x-ray shoot out charged particles? Or did it in some inexplicable manner break the particles of air up into charged pieces? The latter proved to be the case.

At once scientists set out to investigate the nature of these charged fragments of air atoms. Foremost among them was Sir J. J. Thomson, the brilliant English physicist. He found that these particles when set in motion could be easily deflected by means of either a magnetic or an electric field. They behaved in a manner somewhat similar to that of a wire carrying an electric current. By measuring the deflections and the fields causing them, together with the voltage used to set them in motion, he arrived at the velocity with which they were made to move. It was comparable to the velocity of light. Even the slow ones moved at as much as 18,000 miles a second. Similar particles which were

obtained from radium actually reached velocities as high as 160,000 miles a second. These were the so-called electrons, or beta particles, as they are called when radioactive materials are the source. Further experiments led to a knowledge of the ratio of their charge to their mass. It remained for R. A. Millikan to measure these separately at a later date.

The measurement of charge to mass at different velocities led to a somewhat startling result. It was found that the mass was not constant, but increased as the velocity increased, and it was not until the relativity theory came to the rescue that this result was understood.

In addition to the electrons, which were at once identified and measured as described, there was also found to exist another type of particle. These latter particles were at first referred to as canalstrahlen, because first found streaming through a fine hole in a metal part of one of the tubes used to study the electrons. At first these streams of particles defied all efforts to bend them by means of electric and magnetic fields. They were accordingly thought to be similar to light rays, and so quite different in nature from the electrons. Stronger fields succeeded, however, and the streaming specks were identified as positively charged particles, oppositely charged to the negative electrons. The initial failure to turn them in their path had been due to their enor-

mous mass as compared to the electrons. They were found to be about 1,800 times as heavy—equal to the mass of a hydrogen atom.

A notable advance in the study of these newly discovered particles was made when C. T. R. Wilson, then a student with Sir J. J. Thomson, found that their path could be rendered visible by shooting them through water vapor on the point of condensing. The droplets had a decided tendency to condense on the charged particles of air left in the trail of the speeding electrons. This same fact of condensation also offered a means of measuring the charge of electricity on a single electron. By putting a suitable charge on a plate held over the water the droplets could be made to remain suspended. The method, consequently, has sometimes been called the Mohammed's coffin method.

Because of the multiplicity of drops of a variety of sizes it was quite impossible to make the measurement with any degree of accuracy. It was at this point that Prof. Millikan took up the study with results that are more or less familiar to every one. He devised a method that had all the advantages of that of Wilson, but that enabled him to deal with a single drop at a time. For his purpose he found an oil droplet the most suitable. He was able to observe the fall of such a drop under the action of gravity, and its rise, due to the application of an elec-

tric field on the plates between which the drop was suspended. Sometimes a single drop was kept under observation for as much as six hours, and the variations in time of rise as it gained or lost electrons was carefully measured. In this way he was able to measure the charge on an electron with great accuracy, and in fact to prove for the first time that such a thing as an electron really existed. Up to that time it had been thought possible that the ratio of charge to mass remained constant while both varied. No longer could any such thought be entertained. Millikan paved the way for our modern electrical theory.

Only Two Types of Building Blocks Compose All Matter

The next great step forward was taken by a young man in his twenties—Moseley. Moseley was killed in the early days of the war at the age of twenty-six, not long after his epoch-making discovery. It has been frequently said that Moseley's death was one of the greatest losses suffered during the war. He had succeeded in showing conclusively that all atoms were made up of but two building blocks, positive and negative particles, electrons and protons. He had fulfilled an old, old dream of all physicists and chemists—that of reducing all substances to mere differences in architecture. Thus

our ninety-two elements became but different arrangements of two kinds of electrified particles. Iron differs from the air we breathe only in the number and arrangement of these particles; air differs from water, or from gold, or from platinum only in this one respect. The significance of such a contribution needs no elaboration. Moseley has left a great monument to himself that will endure as long as civilization itself.

One may well demand to know how such an achievement was brought about. The answer is, through the agency of the x-ray. Moseley used the x-ray spectrometer, which was already developed by others, for his purpose. X-rays are produced whenever an electron moving at high speed hits a target. The effect is somewhat analogous to hitting a wall with a ball. The energy of the ball is lost, but in its place sound is produced. In Moseley's work the analogy is more truly expressed by replacing the wall by a carillon, each bell—and we will assume there are ninety-two of them—representing an electron. If a ball hits one of these a sound characteristic of that particular bell is produced. So when an electron hits a particular kind of atom an x-ray characteristic of that particular atom will be produced—provided, of course, the electron had enough energy. The characteristic x-ray wavelengths thus produced follow a scale, very much

as do the notes of a musical instrument. From such data he arranged all the atoms in the order of decreasing x-ray wave-lengths, beginning with hydrogen as one and ending with uranium as ninety-two. This is called the atomic number arrangement. It differs from the order of atomic weights in only a few instances. The atomic number of any element is equal to the number of electrons in the atom outside the nucleus. As these are the binders, the so-called valence electrons, which are responsible for chemical combination, the atomic numbers are of much greater importance to the chemist than are the atomic weights. The exact reasoning whereby Moseley was able to identify his x-ray wave-lengths with a particular arrangement of electrons and protons is much too involved to find a place outside of treatises devoted to such subjects.

Is Light Done Up in Bundles?

Before we can attempt to go into the matter of actual arrangement of the atomic building-blocks, we must retrace some of our steps. We have been talking much too glibly about wave-lengths, when, as a matter of fact, we are far from certain that any such things exist. In the early days of the study of light, two theories existed—the wave theory and the corpuscular theory. One held that light consisted of waves,

the other that it was made up of small particles. The latter view was supported by no less a person than Newton. Developments for a time completely discredited the corpuscular theory. Any early twentieth century physicist would have told you unhesitatingly that light was a pure wave phenomenon. But about this time, when all was smug, scientists began to inquire too closely into the distribution of energy from a perfect radiating body. Such a body, usually referred to as a *black* body, does not give off an equal amount of energy in the various wave-lengths, but follows a mound-shaped distribution curve. Attempts to explain this on the classical theories turned out to be futile.

At this point Planck introduced the quantum theory. According to this hypothesis, all radiant energy consists of bundles of energy called quanta, the size of which corresponds inversely to what was formerly called the wave-lengths. Confusing tho it may be, it seems impossible completely to divorce the idea of waves even from the quantum, and we are inclined to think, despite its apparent inconsistency, of a quantum as having a wave associated with it. Fortunately for our peace of mind, modern experiment is tending to show that this position is, after all, justified. We are beginning to see that this fundamental speck of energy has properties of both wave and particle. Stranger still, we now

have evidence that the electron, long regarded strictly as a particle, has also wave characteristics. This may yet lead us to the conclusion that the fundamental unit of energy, the fundamental speck of matter, and the fundamental unit of electricity are all one and the same thing.

The quantum theory, while devised to account for the shape of the radiation curve, at once proved useful in the study of the structure of the atom. Whenever a material is excited to radiation, as by heating to incandescence in the case of a solid or by exciting with an electrical discharge in the case of a gas, it gives off light characteristic of itself. When this light is split up into its component colors it forms what is known as the spectrum of the substance. It is the thumb-print of that particular material. Nothing else will have the same spectrum.

Each of the colors in the spectrum is referred to as a line, for they exhibit themselves merely as lines in the ordinary photograph of the spectrum. Study of these lines in the simpler elements—hydrogen, for example—has shown that they follow a definite plan; that the wave-lengths can be fitted into a mathematical formula, which, by the substitution of the proper constants, will give the wave-lengths of each of the lines which the substance is capable of producing.

It is not a far step to imagine that these lines

or colors must in some way be connected with the arrangement of the parts of the atom, but just how is not so easy to determine. Many scientists have attempted to correlate these lines with atomic structure, but at present none of these theories is accepted as final. Until recently, the generally accepted theory was that of Bohr. Certain shortcomings were of course recognized, but it was more or less expected that further research would clear up some of the mystery. Instead, further research has tended to make the theory more and more untenable. The discovery which has associated a wave form with the electron has been the most damaging to the Bohr theory, and has pointed most favorably to a more recent theory based on what is called wave mechanics.

Atomic Architecture

The Bohr theory, still extremely useful for an understanding of modern physics, is, briefly, somewhat as follows: Each atom is considered to be what in some respects corresponds to a miniature solar system. There is a central positive nucleus which corresponds to our sun. Around this revolve the electrons. The nucleus is a massive affair. It is here that all the measurable mass of the atom is to be found. It consists, in the case of hydrogen, of a single proton. In all other atoms it consists of several positive

particles bound together by electrons. Thus helium, the next simplest atom to hydrogen, has four positive and two negative particles in the nucleus. The electrons outside of this nucleus revolve on orbits which are elliptical, being but slightly off circular paths. For a particular kind of atom these orbits are very definitely determined. There are a limited number of possible orbits. If for any reason an electron leaves one of these orbits it will reappear on another. There is no possibility that it may revolve midway between two of these preferred orbits. Just why these orbits are so definitely fixed has always worried the proponents of this theory. We cannot say why this is so. We can only say that all the evidence points to it as a fact. If it were not so we should never have definite spectra associated with different substances. Each substance, when rendered luminous, would produce a continuous band from one end of the spectrum to the other, if indeed it produced any at all.

This, of course, suggests a question. How is radiation produced by an atom? Our theory tells us that radiation is given off from an atom every time an electron leaves its orbit for one nearer the nucleus. When it does this it loses some of its energy, and it is this energy which is thought to produce the radiation. Thinking back to the quantum theory, we have an explanation for this. This sudden loss of energy

gives us the amount of energy bound up as a quantum. Thus the size of the quanta given off from the atom depends upon the architecture of the atom, and as no two elements have the same configuration no two will produce the same spectrum. By their quanta you shall know them.

Where is the electron while it is going from one orbit, or energy level, to another? And just how does it bundle up the energy and send it out always with the speed of light, 186,000 miles a second? Few have attempted to hazard a guess, and their guesses are of little value. We have quite insufficient data to make speculation at all justifiable.

The more modern wave theory of the atom is almost purely mathematical. It is difficult to draw a physical picture of the atom based on it. Perhaps on this theory the atom can best be described as a series of nebulous charged shells surrounding the nucleus, the density of each shell fading off in each direction along its radius.

Transmutation of the Elements

One cannot leave the subject of atomic structure without a consideration of radioactivity. Here we find a mass of heavy, complicated atoms, such as uranium, gradually disintegrating, becoming one substance after another, until it finally becomes lead. It is natural transmutation. This occurs through a natural expulsion of posi-

tive particles from the nucleus in the form of a so-called alpha particle (which is nothing more than a helium atom minus two of its electrons), or through the expulsion of an electron from the nucleus, the electron in the latter case being called a beta particle because it was not at first identified.

As the material is changed from one substance into another, one of the interesting things is the length of life of the different forms. Only one-half of some substances is transmuted over a period of millions of years. Other substances are changed completely in a few seconds. Radium has a half-life period of about 1,700 years. At the end of 1,700 years half of whatever you had at the beginning of that time will be gone. A radium atom endowed with human intelligence would never believe such a disintegration possible. While we, with millions of atoms in the tiniest speck we can obtain, always find many particles being thrown off, from the atom's point of view it might live for centuries with never one of its neighbors exploding. The atom would believe it as improbable as we would believe a miracle which only one man had seen and whose veracity was far from noteworthy.

One may justifiably wonder how it is possible to determine the half-life period of a substance which lasts for centuries. No one has lived long enough to measure it, and in any case radio-

activity was only discovered at the close of the last century. It is done by counting the number of particles which are given off in any one of several ways: by observing the flashes as they strike a fluorescent screen, by computing the number from the heat effect, or by noting the change in current produced in an ionization chamber. With these data and a knowledge of the total number of atoms present, known from the usual chemical data, one can determine the rate of disintegration and hence the time required for half the material to be used up.

If we have transmutation taking place in the radioactive elements despite any attempt that we are capable of making to stop it, is it not possible, then, to produce transmutation in the lighter elements if we give them some assistance? This can be done.

Rutherford, by bombarding nitrogen with alpha particles from radium, was able to produce hydrogen and helium. Further research proved that the same could be done with several of the light elements. In the case of the intermediate atoms, however, nothing has been done. Thus far it seems hopeless to try to transmute these elements. This is unfortunate, for the group of intermediate substances includes the metals which it has always been man's desire to transmute. It would be of great advantage to us

if we could transmute these, but our only hope now is that our theory may be wrong.

A Ton of Radium

Some time ago one of the products of radioactive disintegration was produced artificially. Lenard succeeded in getting electrons, produced by a high voltage in a vacuum, out into the air. He shot them through a thin metal window. Recently Dr. W. D. Coolidge, by using higher voltages and thinner windows, has succeeded in getting a copious supply of these electrons out into the air. He used voltages as high as 900,000 volts. It is estimated that if he could build a tube to operate on 3,000,000 volts it would be equivalent to a ton of radium. As voltages as high as 5,000,000 volts are now available, it remains only to construct a tube capable of withstanding this high potential difference. Doubtless it will eventually be accomplished. When it is, we shall have at our command a powerful medicinal tool whose uses can at present be no more than vaguely guessed.

The whole theory of the structure of matter is in a decided state of flux. Theories of to-day suggest experiments to be tried to-morrow. They in turn suggest modifications of the theory, which may lead to a wholly new line of thought and to another theory hardly capable of identification with the first. Thus modern science

moves on, always changing, always advancing to new truths. There is a danger that before this is in print it may be altered in some respects by new discoveries. The present sketch will serve, however, to give a reasonable picture of twentieth century physics.

What Is Light?

The subject of radiation is rather comprehensive. It includes in its scope all ether-wave phenomena, beginning with radio waves on the one hand and ending with the minute cosmic waves on the other. Between these limits come the infra-red, our principal heat-bearing waves (sometimes called heat waves), the visible light to which our eyes are sensitive, the ultra-violet so much in the public mind recently because of its therapeutic value, and finally x-rays and the gamma rays from radium. These range all the way from wave-lengths of thousands of meters down to those so short as to be of sub-atomic dimensions. It is, of course, impossible to put definite limits on these; to say where one begins and the other leaves off. We frequently call the same waves infra-red or electromagnetic (radio), depending on the method of detection. If it is a method common to the radio field, we call the waves electromagnetic. If it is one usually employed in making measurements in the infra-red, we call them infra-red waves. Were it not for

the various manifestations which are peculiar to certain wave-length regions, and the discovery and measurement of these independently, all the waves we are talking about should have been called by the same name, probably electromagnetic waves, as they all actually are. There is no difference from one end of the spectrum to the other except in wave-lengths.

We have already had some discussion concerning the relative merits of the quantum theory as opposed to the wave theory. In general the former may be said more nearly to fit the facts for short-wave-length phenomena and the latter for long-wave-length phenomena. Thus x-rays and the ultra-violet lend themselves to explanation on the quantum theory, while radio phenomena are almost always described in terms of waves.

Perhaps the outstanding argument in favor of the quantum theory is the photoelectric effect. When radiation strikes a metal, particularly one of the rare earth metals, such as sodium or potassium, it frees electrons from the metal. The astonishing thing about these electrons is that the speed with which they leave the metal is entirely independent of the intensity of the light which falls on the metal. It may be a candle a foot away or a mile away: the electrons are driven off with the same speed. Only the number of electrons given off differs with distance

from the light. The nearer the light, the more electrons. This we would expect. But if we try to account for this phenomenon by the wave theory, we run into considerable difficulty. The electron speed is found to depend wholly upon the wave-length. The shorter the wave, the greater the velocity with which the electrons come off. It would appear on the wave theory that the electron was only shot off when it had stored up the necessary amount of energy. But if we assume that the light is equally spread out over the metal surface and consider the energy which the emitted electron has, we shall find that it would require a wholly absurd length of time for an electron to acquire the necessary energy to be shot off; yet the instant the light strikes the metal the electrons begin to leave. We might account for this by assuming that these first electrons were almost loaded to capacity before the light was turned on; that they had acquired this from previous exposures. We might assume that our light was only required to pull the trigger, as it were. There is nothing, however, in any of our theories of the atom to give us any comfort in this assumption. In addition, to keep up the supply we should have to have about all the energy which falls upon the exposed metal surface collected in these expelled electrons. All would have to collect energy and hand it over to these few. If we are to think of the

release of energy as due to the light pulling some kind of a trigger and dumping the whole load, we are also at a loss to explain why the load dumped depends upon who pulls the trigger. The distance a bullet travels does not depend upon who sets off the gun, yet this is the case here. Any effort to explain the photoelectric effect on the wave theory proves futile.

Now, on the other hand, let us consider the interference of light. A beam of light may be split into two beams, which may be brought back together again in such a manner as to produce darkness. This, on the wave theory, is brought about by having them meet in such a way that they are a half wave-length apart. To use a water-wave analogy, they are recombined in such a way that a crest of one wave strikes a trough of another. Thus the "upness" of one wave is combined with the "downness" of another, and a zero motion results. Try to explain this on the quantum theory! It requires that you think of two bundles of energy coming together and annihilating each other. We might be able to get around this in some manner if it always happened. But it happens only when they are combined after traveling distances that are different by definite amounts. It is difficult to conceive of a quantum that has its characteristics altered so markedly by such slight path difference as is represented by a half wave-length. Any attempt

to explain interference on the quantum theory can only prove ridiculous.

These two phenomena, the photoelectric effect and interference, are but two outstanding cases where attempts to explain them are confined sharply to the one or the other of the theories. There are many others. Unfortunately, at present we can do nothing about it. We must have more experimental data. With this we may ultimately hope to reconcile these two viewpoints of radiation. At present we can only say that each undoubtedly represents a great deal of truth, but that neither represents the whole truth.

Mass of Electron Increases with Speed

One of the most interesting measurements in the field of radiation is the measurement of the speed of light. Since the beginning of experimental physics there have been many attempts to make this determination. It has been found to be about 186,000 miles a second in air, and differs, of course, with the medium through which it is passing. It is the same in interstellar space as it is on the earth.

Now, in order that a wave should travel there must of necessity be something for it to travel in. Since interstellar space is apparently quite devoid of anything that resembles a medium of material such as we are familiar with, and since

light travels apparently with undiminished energy through distances of thousands of light-years, we have been forced to assume a medium of travel quite different from anything with which we are familiar. This medium has been called the ether. It is weightless, colorless, and lacks all the properties which might enable us to detect it, other than its perfect elasticity, which enables it to carry light-waves.

An important question in regard to this ether is its relation to the earth as it travels in its orbit around the sun. Does it behave as if it were rigidly attached to the earth—with no relative motion? Does the earth pass through it as a bundle of wires might pass through the air? Or does the ether drag after the earth as molasses would drag after a slow-moving paddle? Michelson and Morley set out to investigate this near the close of the last century. They found—and their findings have been frequently verified—that there was no relative motion between the earth and the ether. This was done by measuring the velocity of light both in the direction of and at right angles to the direction of the earth's motion. If there were a drag it should have had an effect on the measured velocity of light, much like that which one would find in a boat in going crosswise or along with the current of the stream.

The result obtained by Michelson and Morley is subject to more than one interpretation. It

might be looked upon as favorable to the quantum theory, as quanta require no medium for their propagation. Other considerations make this not the best interpretation, however. We could assume that the ether is rigid with respect to the earth; but if so, other planets and stars certainly must move with respect to it. We are beyond that stage where we feel justified in considering the earth as the most important speck in the universe. But how else can we account for a failure to observe an ether drift? There is another explanation, but at first it sounds more absurd than either of those just suggested. We assume that the measuring instruments used by Michelson and Morley became shortened in the direction of the earth's motion an amount just sufficient to mask the effect of a drift which actually existed! This is known as the Lorentz-Fitzgerald theory of contraction. Experimenters have tried various substances; but if this contraction takes place, the substances all contract the same amount, as the theory would suggest.

This theory of contraction gains support from measurements on the mass of an electron and its variation with speed. It was found that an electron increased its mass with velocity in such a way that at the velocity of light its mass would be infinitely great. Did this mean that all the equations giving our usual dynamical relations would have to be abandoned in the case of the

electron? Was that an exception to all our classical laws? Not if we accept this theory of contraction. For, strangely enough, the order of this contraction is exactly such as to offset the increased mass and so to leave our relations between mass, length, and time unchanged. The theory was consequently accepted.

Another victory for this theory has been that it is quite in accord with the theory of relativity as developed by Einstein.

IX

MAN'S ENEMIES

Millions a Year for Weeds

It must be confessed that farmers have many troubles. Farm pests cause enormous losses annually. Of these pests weeds are among the most annoying. Their depredations are so quiet, however, that they are less noticed than are those of insects and birds, for example. Nevertheless, they are taking their constant and, in many places, increasing toll annually. Many farms now abandoned as unprofitable would show a profit if this source of loss were even partially under control.

The loss due to weeds is represented in many different items. These might be listed as the cost of competing with weeds, the cost of cultivation, the dockage on inferior grain and seeds, the expense of cutting weeds on highways, and miscellaneous losses such as animal poisoning, and so on.

Undoubtedly the greatest loss due to weeds has been found to be the direct competition of weeds with the cultivated plants, the growing of weeds on land prepared and fertilized for useful plant growth. The damage reaches into enormous figures. Some time ago the Indiana Experiment

Station made a survey of these losses for various crops. For corn they found a reduction in yield of ten per cent., due to weeds; for tame hay, 3 to 16 per cent.; potatoes, 6 to 10 per cent; spring grain, 12 to 15 per cent.; and winter grain, 5 to 9 per cent. Using these figures as a basis, Dr. A. L. Stone, of the Wisconsin Department of Agriculture, estimates the annual loss to that State from this cause at $25,604,998. This is a direct loss due to occupation of space by weeds which was intended for useful plants.

If we take the second item of loss, cost of cultivation, we arrive at another large figure on the wrong side of the ledger, which helps to make farm relief a national problem. Few farmers cultivate wholly for the conservation of soil moisture, but are at the same time striving to keep down weed competition. The United States Department of Agriculture estimates that the cost of cultivation is one-sixth of the total cost of crop production. One-half of this item is assigned to weed control. Thus one-twelfth of the cost of production is for weed eradication. In Wisconsin, according to Dr. Stone, this presents an annual bill to the farmers of that State of $13,127,775.

Our next item is that of dockage. Whenever grain or seeds are presented to the dealer, the price is lessened if the product is dirty or contains weed-seed or other foreign matter. With

modern methods of harvesting there is little dirt or chaff likely to be found in the grain. Any foreign matter is almost certain to be nothing other than weed-seed. It is agreed among experts that a conservative estimate for dockage is one per cent. for grain and ten per cent. for clover. On this basis the State of Wisconsin, for which figures are available, loses each year, in lowered selling price, the sum of $5,298,440.

Pulling and cutting the weeds on the farm and along the highways, as required by law in most States, also presents a large figure, even on the most conservative estimate. If one allow but five dollars a year in farm labor for cutting weeds on the farm, and three dollars a year in labor or in taxes for cutting the weeds along highways adjacent to farm lands, the total loss due to weeds becomes, for Wisconsin, according to Dr. Stone, $1,545,152.

If now we lump together all such losses as the poisoning of farm animals, the tainting of dairy products by such plants as wild onion, the nuisance caused by vine-like plants in harvesting, damage to animals due to thorns, burs, etc., we may safely set down the figure $500,000 as the loss due to these various causes. This gives us a grand total of $46,076,365 as the loss due to weeds in a single State.

Naturally such a condition is attracting considerable attention on the part of agricultural

agencies. But it must be admitted that the weed problem is not diminishing noticeably. Our present means of easy communication are adding to the problem. Seeds of noxious weeds are now carried rapidly over considerable distances on the wheels of vehicles. It is a lucky farmer who does not discover one or more new weeds on his farm each season. Here is a problem which will test the ingenuity of our best scientists.

Insect War

The second great problem of our farmers is insect control. This is a problem that in general is much more interesting and consequently receives much more attention than the weed problem. Probably it is because we are inclined to think of the insect as having intelligence and definitely attempting to bring about the ruin of man. The battle between insect and man has long been a favorite topic of the speculative writer. That there is some possibility of this very thing happening cannot be denied. Insects were here on the earth long before the advent of man, and they may remain after he has left. The insect may have much to do with man's going.

If one were to attempt to give but a brief description of all our harmful insects it would fill a large volume. Consequently we must restrict ourselves to a survey of the methods of controlling only a few.

In the West the Mormon cricket must be numbered amongst our worst enemies, and because this insect marches in large orderly armies, and thus appears to be definitely directing an attack on humanity, the methods of fighting it are perhaps the most interesting of all.

The Mormon cricket was so called because of its attack, in 1848, on an early Mormon settlement near where Salt Lake City now stands. The insects descended upon the colony and threatened its extinction. Men, women and children worked until exhausted in an attempt to save something of their crops. Finally a flock of gulls from Salt Lake appeared and did what the farmers had failed to do. Because of this apparently miraculous salvation, a monument was erected to the gulls. Thus first notice of these insects came in a romantic manner, and the romantic has been associated with them ever since.

At a certain stage of development they begin their march straight across country. Why they do this no one knows. They will often leave a perfectly good feeding ground for a comparatively barren country. In their march they travel about three-quarters of a mile per day. They climb over large obstacles in their path, and will even go over a house or barn in preference to going around it. They can climb anything but a smooth hard surface.

One of the best methods of heading off the march is to construct tin fences, a foot or so high, across the path. These are of smooth tin, and inclined slightly. The insects cannot climb this. Often ten or twelve miles of such fence is used. At intervals along the fence excavations are made and lined with tin. The insects trapped in these are sprayed with gasoline and burned. They are then shoveled out to make room for further catches. So great are the quantities caught that some commercial concerns have sought to extract the oil from them for commercial purposes, and to use the insects themselves for poultry and hog feed. Neither of these attempts, however, has thus far proved a success.

In addition to using this warlike method of trenches and metal fences, the insect armies are attacked in the rear by poison-dust guns. Where land formation permits, the guns are mounted on trucks or wagons. Otherwise they may be used on horseback. Smaller ones may be used by men on foot. These guns spray calcium arsenate, which kills the insects, not immediately, but in from thirty to seventy hours. Fortunately, they stop feeding almost at once, however. They are killed by licking the dust off their feet, not by eating the plants on which it is sprayed. Thus do we battle with one of our most spectacular insect enemies.

In the case of the boll-weevil, the use of

airplanes to spray poisons over the affected fields adds again to the warlike appearance of insect-control methods. In the case of this pest we have an excellent argument in favor of diversification of crops, another method of control. Where field after field of cotton is grown without a break, conditions are ideal for the spread of the insects. If the continuity is broken by some crop which the boll-weevil does not attack, it offers a barrier to its spread.

A method of insect destruction now beginning to be used, and occupying considerable attention of the scientists, is that of introducing parasites which prey upon and destroy the insects. Many parasites are being imported for this purpose in the case of the Japanese beetle. Orchard-insect parasites also are being bred in this country and shipped to infested regions. Thus we attempt to make the world safe for mankind.

Get Acquainted with Insects

In insect control, one of the first necessities is to know your insect. It is not enough to know merely that it has arrived and must be fought by some material which you may at the moment happen to have handy. You must plan your attack intelligently. It is essential that you know much about the insect's habits, particularly its

habits of feeding, its life cycle, and its breeding places.

It is useless, for example, to spray with Paris green a plant which is infested with plant-lice or aphids. The poison stays on the outside of the leaf, while the insect feeds on the juices inside the cells, which it gets by puncturing the leaf. The pest is immune to such treatment. On the other hand, such insects as slugs, grasshoppers, caterpillars, and beetles have jaws and actually bite off and consume the leaves. Poisons which coat the outside of the leaf are accordingly useful in these cases. It is not difficult to determine which type of insect is at work. In the first case the leaves wither and die, in the second case parts of the leaves will be eaten away. Insects sometimes fall into neither of these classes and will not eat poisoned leaves. The Mormon cricket is poisoned by getting the insecticide on its feet, which it subsequently takes into the system by licking.

Another thing to be considered is the proper time of application. Knowing the life cycle of the insect, one can predict its appearance and spray beforehand. Again, there are those insects whose appearance can be awaited and sprayed as convenient. One should remember that the rate of reproduction is an important factor here. In the case of aphids, where this rate is ex-

tremely rapid, no time should be lost after the pest has been observed.

The time of day at which the application of the poison is made is likewise of considerable importance in some cases. Poison-bran bait is used for both cutworms and grasshoppers, but for the former it is best applied in the evening, for the latter in the morning. This is because the cutworm feeds at night, while the grasshopper feeds in the early morning. In the case of the chrysanthemum midge, the proper time to fumigate is shortly after midnight. Inconvenient tho such a procedure may be, that is nevertheless the time at which the insect emerges for feeding. The time to get it is when it is susceptible to attack.

Again we are greatly assisted if we know where to look for the insect's breeding place. Here we may be able to attack when it is in a position, or in a stage of development, in which it cannot defend itself. White grubs, cutworms, and wire-worms breed in the sod, which indicates the desirability of soil treatment in their eradication. Other insects have their period of development in weeds which, apart from their own injurious effect, are likewise undesirable from this point of view and should not be allowed to grow.

Plant growers should not fail to make a thorough study of the life and habits of every insect which they are called upon to combat. They

should know just what remedy to apply and how to apply it. Without a knowledge of the insect itself it is difficult to determine the measure of success which the remedy is having. Study of insects should be as much a part of the plant grower's concern as is the study of the soil. It is almost equally important.

Termites Need Parasites to Digest Their Food

Termites, frequently referred to as "white ants," altho they are not in fact ants, constitute an interesting yet dangerous menace. These creatures, of which there are 1,600 known varieties, live in ant-like colonies, have a division of labor among them similar to that of ants, and in general follow somewhat the plan of living of ants. Their life cycle consists of three stages, the egg, the immature form or nymph, and the adult form, which may be divided into classes. There are the workers, the soldiers, and those which exercise the sex functions.

Termites are soft-bodied insects and seclude themselves underground or within wood. The workers, which do the work of excavation within the earth as the colony requires, are blind and avoid the light. They are seldom seen. The sexual individuals are winged, have eyes, and at certain seasons of the year migrate, in what might be called swarms, and establish new colonies.

Contrary to popular opinion, these pests are

native to this country and have long inhabited our forests. Only recently, however, have they attacked the settled regions as a result of the destruction of great forest areas. The thing which makes them such unwelcome visitors is their food habits. They can live on either live or dead wood, and therefore can damage all sorts of wooden structures.

The termites may, in general, be divided into two classes. The subterranean species never come above ground, but confine their attacks to wood which they find in contact with the earth. They usually follow the grain in the wood and honeycomb it. They are particularly dangerous in that there is no evidence visible above the ground of what is going on below.

The non-subterranean termites do not need contact with the moist ground to maintain life, and will attack wood above ground. They do not usually follow the grain of the wood, and their activities are easily detected. It is interesting to note how these insects are able to digest dry wood and to secure nourishment from it. This is possible only if they are acting as hosts to suitable organisms. In the intestines of termites are found fauna and flora of great diversity and in great numbers. Protozoa, amebas, spirochetes, and fungi are present. Some of the protozoa contain enzymes which digest the wood for the ter-

mites. Without this guest the termite could not survive on dry wood.

Because of lack of information on the habits of termites and of the infested regions, many buildings are erected annually without in any way providing for protection from them. After damage has occurred it is frequently a matter of great expense to rectify the error, to reconstruct the building, to make it immune from attack. One method has been, of course, to keep all wood from contact with the ground. Frequently, however, the termites will build a grayish shelter-tube over cement to reach the wood. These are easily seen and destroyed.

Because no known wood is immune to attack (the heart-wood of some trees is highly resistant), methods of chemical treatment have been devised by chemists of the United States Department of Agriculture. For wood in contact with the ground, the use of coal-tar creosote is recommended. For wood intended for use above ground, treatment with zinc chlorid has proved most effective.

Have Insects Ears?

Can insects hear? In general they do not respond to any sounds that we make, and as a result the conclusion has been reached that they are quite deaf. This is not a fair conclusion. True, you may shout at a fly as much as you

choose without exciting in it any evidence that you are heard. But there is nothing you are likely to shout that will be of much interest to the fly. Its lack of reaction may only prove that you are unintelligible to it. We, perhaps like the fly, only react to those sounds which interest us or which convey some meaning to us. To the fly you make but one more sound in the great quantity of sound made by humans which cannot possibly mean anything to the insect. It is not surprizing that it does not respond.

Experimenters have, however, found a few insects which respond to sounds which we can make. Silkworm moths have been found to lift their wings when an organ pipe was sounded. Every precaution was taken to keep the draft of air used to blow the pipe from directly reaching them. Failure to avoid a disturbance from this cause has led many observers to assume that the insects were responding to sound when they were in fact responding to the movement of air. A number of species of under-wing moths have also been found to respond to a high-pitched whistle, either by flying or by lifting their wings as if to fly. Two species of caterpillars have also been shown to respond to sound by motion of their bodies. This response has been definitely associated with hairs on the body. When these hairs are removed by singeing, or when they are made inactive by a coating of

water or of shellac, the response ceases. This does not mean, of course, that it is the hairs which hear, but rather that, as in the human external ear, they are connected with internal sensory organs.

Searching for what corresponds to an external ear in insects has not been very fruitful. There are few which have any organ that remotely resembles the external ear of the human. Crickets and katydids, however, have an earlike structure on their front legs, and investigation shows that these are connected closely with enlarged air-tubes such as are present in great numbers in every insect body for breathing purposes. The sensory organs associated with these cells are different from any other in the insect body. They are characterized by having the axis fiber stretched through the center of a hollow tube filled with liquid. There are large numbers of these cells near the ear on the front legs of crickets and katydids, and these are all connected to the central nervous system. They have every appearance of being intended as organs of hearing. Suspecting this, scientists have searched other insects for similar cells. These have in many cases been found, frequently in the most unexpected places on the insect's body, and not associated with any external organ obviously intended for hearing.

Suppose, now, that we are satisfied that these

organs are in fact organs of hearing. What guaranty have we that they are intended to hear the frequencies to which the human ear is sensitive? We are limited by a maximum upper range of 20,000 vibrations per second, a value that would be high for even an abnormal individual. Possibly the insect has a different range. Its organs of hearing might begin where ours leave off. It is fair to assume that insects should be capable of hearing the sounds which they themselves make, and Professor B. B. Fulton, of the North Carolina State College, has made use of this likelihood in his study of insect hearing.

Observing that certain species of crickets and katydids sing in unison, he determined to use this fact in his experiments. These insects keep such perfect time that the song of ten or a dozen is often mistaken as that of a single individual. Professor Fulton collected such insects in cages, and after satisfying himself that their singing was synchronous, he cut off the front legs of half of them just above the hearing organs. These insects he placed in an adjacent cage, far enough from the others so that he could distinguish the song from each group. He found in every case that the song of those with the sensory organs removed was entirely haphazard. They were like a group of deaf musicians playing in the dark. Occasionally a pair would get in their chirps together by accident, but they would

gradually depart from the synchronism again. The normal insects were always together in their song. This proves that, certainly in the case of these insects, they not only hear, but their sensory organs have been definitely located. There is every reason to believe that many other insects may also hear with less fully developed ear organs, which may not always be sensitive to the same sounds that affect humans.

Soil Erosion

One great farm loss which sneaks upon the farmer, more or less unawares, is soil erosion. The fertility of soil is, of course, depleted by the crops which it supports. This fertility can be replaced. What cannot be replaced, however, is soil washed away and out to sea. Not only is the plant food gone, but the soil itself which is necessary to support it. In this way many of our good farms are slowly but steadily becoming poor ones. The farmer's first warning is usually in bits of clay or rock protruding through the soil of what up to then had been a good, rolling field. Even then he may not take the necessary steps and sow the field with a suitable crop to preserve its soil.

"The Mississippi River alone," says Mr. H. H. Bennett of the United States Bureau of Chemistry and Soils, "delivers to the sea every year 528,000,000 tons of suspended matter, most

of which represents wash from the surface of the land, the richest part of the soil. In addition, more than a third as much is poured into the Gulf of Mexico in the form of dissolved matter, and it is not known how much more is swept along the bottom of the Mississippi. What is still more important is the material removed from the fields and deposited somewhere along this great watery highway to the sea, usually upon valley lands, where it is not needed, and in channels of streams where it does much damage. Every year this temporarily stranded material amounts to many times the combined quantity that enters the ocean."

It is estimated that erosion removes as much as twenty-one times the amount of plant food taken out by the crops.

In many cases land is cleared and no provision made for reforestation where it is perfectly evident that erosion will occur. It is in such places as these that the great gullies due to erosion occur. Nor is the damage restricted to this one locality. It may destroy good valleys by depositing in them. It may, as has happened, ruin established orchards of great value several miles from the eroded land.

Examples of erosion are common, as one sees in traveling about the country. Many eroded localities can be seen in a day's journey in almost any direction. In most cases nothing is being

done to prevent further damage. Many interesting cases have been reported. In one place where once stood a school-house there are now gullies a hundred feet deep. It is a desolate section, desolate beyond reclaiming. Much of the best bottom land in New England was permanently destroyed by the flood of 1927. There was spread over it a deep layer of loose sand and gravel of low water-holding capacity. Far up the Missouri River Valley, a region of 120 acres has been known to lose from eight to forty inches of soil since the clearing forty years ago. This has taken place slowly but continually. Each muddy stream flowing down the roadside is carrying off its bit of soil unless some provision is made to collect it. It is estimated by Mr. Bennett that soil erosion is costing the farmers as much as $200,000,000 annually. This bill is presented to the citizens of America every year. We are told that if this keeps up we shall soon be no longer a nation exporting farm products, in spite of our increasing farm efficiency through machinery.

All this can, of course, be prevented by proper scientific farm operation. In most cases the soil, prone to erosion, can be used to raise crops which will hold the soil in place. In many cases it can be prevented by cheap methods of terracing. In this way the violence of the drain is stopped and the soil is deposited quickly from

the slow-running water. The time has departed when we could think of the soil as free. Dirt is cheap only in small quantities. Fertile land on a nation-wide scale must not be dealt with thoughtlessly.

X

WE IMPROVE PLANT LIFE

Effect of Light on Plants

THE discovery of the profound effects attendant upon ray-therapy in the case of animal life has naturally turned the attention of botanists to similar studies in the case of plants. Their efforts have been well rewarded. A number of questions will at once spring to the mind of the inquisitive person. Since green vegetables have an anti-rachitic effect, is it because of their long exposure to the ultra-violet of the sun? Is the ultra-violet of the sun at all necessary or advantageous to the plant? We know that a plant utilizes carbon dioxid gas in its process of food synthesis, yet this gas, so necessary for plant growth, is poisonous to the human being when it comes in large quantities. Certainly, in this respect, the plant behaves very differently from the animal. Perhaps it also does so in numerous other respects. Let us see what the present state of our knowledge really is. First of all, we do not as yet know to a certainty what improvement, if any, in anti-rachitic effect may be conferred upon the plant by irradiation with ultra-violet. Presumably, however, there would be some benefit.

That the ultra-violet has an effect upon plant-growth directly, there is no question. But the effect is not always beneficial. Some plants do much better without it. In many cases it greatly increases the plant foliage. On the other hand, if we look into the effect of the infra-red, the light just off the other end of the visible spectrum, we find a very considerable change. The plant grown in this light assumes a slender, vine-like nature, and winds around its support. It behaves much like a plant grown in the dark, except that it remains green. Side-shoots and leaves have a tendency to curl up. The cell walls are thinner. The flowering is delayed. In general, the plant is weakened. As a result of such experiments it has been established that in general a plant is best off which is provided with all the constituents of natural sunlight.

Another interesting discovery regarding the effect of light on plants has been made in connection with the effect of varying the number of daylight hours. Here it can be said that the plant growth is hastened proportionately, provided that the plant is at the same time supplied with an extra amount of carbon dioxid gas. Plants, through the agency of the sun's rays, synthesize carbon dioxid and water into carbohydrates. Unless a sufficient amount of carbon dioxid is available to make it possible for the plant to utilize the extra sunlight hours, nothing is

gained. Clover, barley, and soy beans are plants which are notably benefited by extra hours of sunlight. Some plants, notably tomatoes, are benefited only by a few extra hours of the sun's rays. If carried too far, the sunshine treatment will result in killing the plant. Apparently plants, like humans, require a certain amount of rest for their well-being, and if this is not given to them they react in much the same way as humans.

It has often been suggested that the taste of vegetables or fruit grown in a greenhouse differs from that of those food plants grown in the open, because of the filtering out of the ultra-violet by the glass of the roof. It has been thought that the so-called "flat" taste of greenhouse plants might be explained in this way. Whether or not there is any foundation for this belief is still a question. If it could be definitely established that such is the case, an improvement in our hot-house products could be made by growing them under ultra-violet-transmitting glass.

Effect of X-Rays on Plants

The study of the effect of radiations on plant life would not be complete without including some experiments on the effect of x-rays. Much work in this field has been done by Professor T. H. Goodspeed, of the University of California. He has carried on extensive experiments over a

period of two years on the effects of these rays on tobacco plants. The results can best be summed up in his own words:

"The correct dosage of x-rays or of the gamma rays of radium applied to any tissue of the tobacco plant which is capable of growth or is concerned with the process of sexual reproduction is followed by variation.

"Some of the variations which can thus be reproduced are inherited, since they affect the character of hereditary material. The other variations are not in the same sense inherited, because they affect the amount rather than the quality of the hereditary material. From a scientific point of view both sorts of alteration are of interest, because they parallel the types of changes known to go on in the hereditary material of plants and animals in nature or under domestication.

"The dry seeds of the tobacco plant," Professor Goodspeed continues, "are very resistant to these high-frequency radiations. Only the heaviest dosage will kill them, but when the seeds have begun to grow, a relatively light dosage proves to be lethal. Such plants as survive are often chimers—or mosaics—some tissues containing one alteration in the hereditary material, others being different in this respect.

"This same type of effect follows treatment of the growing points of the stems of young

plants. Practical application of these results may be possible. If the horticulturist can obtain a similar mosaic condition in fruit trees, for example, then he could select the branch 'sports' which were of value or interest and propagate them by cuttings."

Public attention has already been called to the fact that x-ray treatments of immature sex cells of tobacco plants have resulted in great variation in plants resulting from the union of these plants. Work has been going on for more than two years on the effects of x-rays and the gamma rays of radium on seeds and seedlings and tissues of other sorts. Later generations have been grown from the original products of x-rayed sex cells.

More than 10,000 plants illustrating the effects of treatment on various tissues are now being grown in the botanical gardens of the university.

What the future may bring in the way of further development of such studies can only be a matter of conjecture. It appears, however, that such studies will be of the greatest interest and value to the human race.

Gassing Plants

The ripening effect which results from the gassing of certain fruits and vegetables with ethylene gas is already well known. Oranges,

tomatoes, bananas, and many others respond to this treatment. When potatoes are taken from the ground they will not immediately sprout. The dried-looking buds, which are in the eyes of the potato, require some time of rest before they are ready to develop. This rest period was for a long time thought to be a necessary element in the plant cycle. Now we know that it can be shortened by various means without harm to the plants which come from this seed. It was at first found that the ethylene gas, which hastened ripening, also had a mild stimulating effect on potatoes; it shortened slightly a dormant period. But the advantage gained was too slight to be of any value. Dr. F. E. Denny, of the Boyce Thompson Institute for Plant Research, has shown, however, that certain derivatives of ethylene are much more potent than the gas itself in this respect. Ethylene chlorhydrin and ethylene dichlorid are effective, as is also sodium thiocyanate. Good fortune is also in evidence here, in that these materials, being liquids, are much easier to handle than is the ethylene itself. The liquid, when used, is vaporized by blowing air across it. The vapor soon fills an airtight room.

The result of the treatment of potatoes by this method has been not merely to shorten the period of dormancy, but actually to eliminate it entirely. Potatoes taken from the ground can be

replanted as soon as they have been treated. This bids fair eventually to revolutionize potato-growing in this country. It will make the growing of two crops a year the rule over a large section of the country. It will not affect the far South, where this is already possible, nor the North, where the season would in any case be sufficient for but a single crop. In that large midway section, however, beginning with southern New Jersey, we may soon expect to see two crops grown regularly. Of this the late Professor J. T. Rosa, of the College of Agriculture, University of California, wrote:

"The practical application of the dormancy-breaking treatments will be used mainly in the Southern States and in California. From southern Jersey to Texas and as far north as the Ohio and Missouri Rivers, the growing season is long enough to produce two crops of potatoes a year. To do this economically it is desirable to use the potatoes produced in the spring crop as seed for the fall crop. Except in the far South, the period between the digging of the one and the planting of the other is too short for the tubers to pass through their natural dormancy. Hence the need for treatments to hasten sprouting.

"Another instance of the usefulness of stimulation treatments is the treating of seed shipped from the Northern States to Bermuda, Florida,

and California for planting a winter crop. This seed is dormant when received by the Southern growers, who can increase the earliness and yield of their crops by stimulation treatments. These treatments may also be useful in seed-growing districts. For seed purposes medium to small tubers are desired. The proportion of such tubers can be increased and the overly large tubers reduced by treatments that result in an increased number of stalks with a greater number of tubers per plant.''

Temperature and Plant Life

The use of such chemical methods as the one just described is sure to be extended greatly now that an impetus has been given to research of this character by the success with potatoes. Methods of treatment for giving greater percentage germination of seeds will also be discovered. At the present time much is being done in the study of purely physical effects, such as that of temperature.

Temperature alone has been found to have a very marked effect on the dormancy period of potatoes. For many years it has been generally believed by farmers that keeping potatoes in cold storage for a few weeks would have the desired effect, and it has not been uncommon for farmers to put their seed-potatoes in cold storage for a short time before planting. Experiments at

the College of Agriculture, University of California, have shown conclusively, however, that such storage has in fact no value. There is little difference in the rate of sprouting after three or four weeks of storage at 40, 48, 55 and 70 degrees Fahrenheit. On the other hand, potatoes stored at 80 to 86 degrees Fahrenheit were ready for replanting in about three weeks. They sprouted rapidly, and the plants were above ground in twenty-four days. The usual dormant period is from three to four months. Different varieties respond somewhat differently to this treatment.

From the standpoint of reforestation, the Boyce Thompson Institute for Plant Research has made a valuable contribution to the hastening of germination of southern pine by means of special treatment. In Louisiana the low percentage and irregular germination of the pine has seriously hindered reforestation work. The treatment given the seeds consisted of stratification in moist peat moss at 0 to 5 degrees centigrade. Seeds so treated for one to two months gave 82 per cent. germination in twenty-two days, while seed not so treated gave but 41 per cent. germination in 100 days. The percentage of germination depends somewhat upon the species of pine, but in forty-eight days the after-ripened seeds of short-leaf, slash, and loblolly pine gave 62.60 and 70 per cent. germination,

respectively, while the control seeds, not so treated, had not appeared above the ground at all. The saving in time, money, labor and expense which this simple method promises is enormous.

Temperature appears also to promise a satisfactory treatment for cuttings intended for planting. A great deal of work has been done with holly cuttings at the Boyce Thompson Institute. The increasing popularity of holly for decorations during the Christmas season has resulted in a demand which the growers find themselves unable to meet. The result has been that an acute situation has developed where it is essential to increase at once the parent stock. Dr. P. W. Zimmerman has developed a method which promises a rapid increase in these plants by cuttings. The cuttings are stored from four to five months in about five inches of half-and-half peat moss and sand. The temperature is kept between sixty-five and seventy-five degrees Fahrenheit. Using current-season stems, these were so accelerated as to produce berries the first season. As the propagation of holly from seeds has been very difficult, and as they did not respond well to propagation by cuttings as usually carried out, this treatment will prove of great value to the growers.

These few examples of what has been accomplished by gas and temperature treatments in the

matter of plant propagation are only suggestions of what the future may bring. The possibilities are indeed fascinating. We may yet bring Nature under our command.

Camel Plants

The camel has long been thought of as a symbol of dryness. His ability to live for many days without water has been considered remarkable. But, after all, compared with some other forms of life, his feats in this respect are as nothing. Many plants can exist without water for months. But, you say, these are plants, not animals. Yet, nevertheless, the fact that a camel walks and these plants do not does not make their feat the less remarkable.

In thinking of camel plants one at once calls to mind the cactus plants of the desert regions. These have a remarkable ability to store water, being admirably designed for this purpose. First of all, their roots spread out over a wide area just below the surface of the soil. This enables them to absorb immediately great quantities of water from even a slight rainfall. Their thick leaves, covered as they are with a coating which may almost be described as rubber-like, are intended to give up a minimum amount of this water, which is stored in the fleshy part of the plant. So well worked out is the system of water collection and retention that a cactus plant may

be uprooted for months and still carry on its life. Some have even been known to live a year and a half after uprooting.

But not all plants intended to survive on a minimum of water are necessarily desert plants. There are many dry spots, such as thinly covered rocks, where the plants must show this same ability. Every gardener also knows the great advantage which many weeds have in this regard. Purslane, for instance, will take root again days after it has been hoed loose.

Again there are those plants which must store water against a seasonal drought. This is often done by means of underground bulbs, as in the case of the wild onion. Describing this noteworthy example in point, Professor E. L. Pickett, of the State College of Washington, writes:

"A wild onion, common throughout the western part of the United States, produces its leaves and clusters of light pink flowers in April. By the first of June both are dead and dry. The bulbs, usually less than one-half inch in diameter, are six to eight inches below the surface. Through the summer months the soil becomes dust-dry, and there is no rain before September or October. A hundred of these bulbs were carefully taken up one May. They were weighed and then kept in a dry room for more than eight months. At the end of that time they showed only an insignificant loss of weight. At another

time a number of nice specimens were taken when in full flower. They were carefully pressed and dried, without crushing the bulbs, and put away in a dry-storage room. Twelve months later these specimens were taken out for examination and were found with clusters of new flower buds. No water other than that in the bulbs had come near these plants at any time during the year.''

The amount of water which it is possible to store in underground roots, stems, bulbs, and so on, is enormous. Roots weighing more than fifty pounds are not uncommon with some members of the gourd family, and these roots are found to be 80 or 90 per cent. water. The retention of water in such underground parts is often aided by coverings that are quite cork-like in their nature and almost impervious to water.

Other plants survive dry seasons by reaching maturity in the short rainy season, producing seeds, and dying. The seeds, which contain but five to ten per cent. of water, are carried over to the next rainy season. Common grains are often able to live for fifteen or twenty years and germinate successfully. The stories of seeds taken from ancient tombs and made to germinate after centuries probably have no basis in fact. Most seeds must be planted immediately after maturity.

XI

NEW TRICKS IN CULTIVATING THE EARTH

Fur-Farming

As is the case with almost every industry, the farm has constantly opened to it the possibility of producing new products. The alert scientific farmer is never slow in taking advantage of them. One of the latest of these farm opportunities is fur-farming. In the past such animals as fox, mink, beaver, and lynx have been farmed by specialists with profit; but such enterprises have presented little opportunity to the busy farmer. The latest fur to be farmed is the muskrat. This many farmers are well equipped to produce without cost for labor, food or housing.

Only recently has the muskrat been worth considering. The trapper who could get only fifteen or twenty cents for a muskrat pelt spent his time on larger game. The muskrat was left for the farm boy. But at the end of the World War, when this animal brought as much as ten dollars a pelt, and later stabilized at around two dollars, it took on a new prominence. Further, the furriers found the pelt an easy one to dye in such a way as to resemble more expensive furs. It now masquerades under various

fancy names. This opened up the opportunity for the farmer.

The muskrat lives in swamps and marshy land, places which are of little value normally. Perhaps some such places could be drained and made to produce a grain or grass crop, as many have been; but there is an enormous acreage that it would never pay to attempt to develop. Such swamps may produce at best a few tons of coarse marsh hay, hardly worth gathering. A surprizing number of farms have at least a few such acres. These are the places where the muskrat thrives. He finds his own food for the winter in the grasses of the swamp. He stores up his own winter food supply. He is not subject to any known disease. It is evident that the muskrat farmer is due to have but little care of the animals. In the event that the food supply runs short, as might happen if the land were allowed to become overstocked, a bushel of turnips or carrots will feed a muskrat for three months.

The only precaution which the farmer must take for the care of the animal is to protect it from its natural enemies. Other animals can be kept out of the muskrat farm by surrounding it with a tight wire fence a few feet high and buried a few feet under ground. Such a fence is not necessary to keep the muskrat from run-

ning away, for he is living under natural conditions and will have no desire to migrate.

The farmer's only concern, once his farm has been established, is to gather pelts. As the female will produce from twenty-five to fifty young a year, it would seem that this catch should occupy his winter months.

In Canada this type of farming is being encouraged by the Government. Waste lands are being leased out for the purpose of such farming, at the rate of twenty-five cents an acre for the first three years and one dollar an acre per year from then on.

The muskrat industry has reached a high state of development on the coast of Maryland. Much of the land is subject to tidal overflow and is valueless for any other purpose. Of these marshes a United States Department of Agriculture Bulletin says: "Now, owing to the increased value of fur, many of the marshes, measured by actual income, are worth more than the cultivated lands in the same vicinity."

One should not forget that in this district the animals are also sold for food under the name of marsh rabbit. There seems no possible objection to this, as the muskrat is clean in its feeding. It is almost wholly herbivorous, living on the weeds and grasses of the marsh. Its only animal food is mussels and slow-moving fish such as the carp. The table-use of the muskrat offers

an additional income which the farming of no other fur-bearing animal produces.

It is only to be expected that as civilization advances we should turn to fur-farming. In the early days man's food depended upon his ability as a hunter, and upon the natural vegetation found in his neighborhood. The science of agriculture has now changed all that. In the same way it will remove our dependence for furs on the haphazard methods of the trapper. The trapper can now settle down as a regular member of the community and make his living off his own fur-farm.

Ocean Farming

As we depend no longer for our furs upon chance, neither do we now depend upon the occasional foraging of seafarers for our ocean foods. The farmer has gone to sea. No longer do we need to depend upon natural conditions for a good crop of oysters. The bivalves are now produced by artificial cultivation. At the proper season the baby oysters, or spats, are transplanted to suitable waters, there to mature, just as plants might be set out in the garden. New areas are constantly being brought under cultivation; the oyster-beds along Long Island, thus formed, extend for miles. No longer is it anybody's oyster, for these beds are protected by law just as the farmer's fields are protected. In

Japan and in France the oyster is even more intensively cultivated than in America.

Oysters whose shells are suitable to make buttons are also farmed. The United States Bureau of Fisheries operates a large experiment station on the Mississippi River to assist the pearl-oyster industry. Hundreds of tons of shells are produced annually by artificial cultivation.

When one realizes that five-sevenths of the earth's surface is covered with water, it is evident that the increasing population is sure to make ocean farming more urgent. This offers a solution to the problem of food supply for some time to come, a fact which is more evident when one realizes that farming on the ocean is not confined to a plane, as is earth farming, but is really three-dimensional. Every ocean level has its own kind of life. As we go down deeper and deeper we find constantly changing ocean inhabitants. It is a multi-storied farm. Scientists are now experimenting with the propagation of the useful sponges, and with the raising of tortoises for tortoise-shell and for food.

In the past we have simply harvested those things which the ocean had to offer. So great has been this industry, however, that there has been taken from the waters of the United States and Alaska about three billion tons of fish annually. Little attempt has been made toward the restocking of this vast food store. In the case of salmon

the time has come, however, to give more serious thought to the farm aspect of the problem. Protection during the spawning season is not enough. In the end we must expect to farm our fish. Two of the oldest salmon rivers in the country, the first to be fished by white men, were the San Joaquin and the Sacramento. Through the water-power projects that have been constructed along these rivers the spawning ground has been reduced from a length of about 6,000 miles to less than 600. This is a problem of ocean farming that needs immediate attention.

We have already been warned of the diminishing supply of whales. Here also is a problem of ocean cultivation. In the future we may expect to see even the whaling industry put upon a farming basis. If the constructive efforts of man are not extended to this and similar fields, many members of our sea fauna may soon disappear.

Forestry

We have long since passed beyond the stage where we depend upon foraging for our food, and are in a stage of transition as regards our furs, while we are fast approaching that stage in forest products. We have made terrible inroads upon our natural forests, and must now begin to farm trees just as we do other plants. No longer can we rely upon bounteous nature to

supply our needs in this respect. Her methods were never intended to cope with the devastating mechanical devices which man has devised. At the present time there are in the United States no less than 300,000,000 acres of unused forest land. We must begin to cultivate this.

One of the drawbacks to forest farming in the past has been the feeling that one must wait too long for returns. This is because the problem has not been sufficiently investigated. If one were to start a forest of oaks, or some other slow-growing tree, the forest products might not repay one for the work in a lifetime, even remembering that there is much to be taken out of a forest before the trees mature. Such projects are for those authorities whose life is more extended. Many towns and villages have taken over and managed forests scientifically. Those that have done so over a number of years have profited greatly. There are villages in the United States at the present time which do not tax their residents, because all expenses of local government are met by products from municipal forests. The same is true in many places in Europe. Besides this source of profit, the forests offer a place of recreation to the inhabitants of the section. It is a venture that no progressive town should overlook.

In much the same way corporations whose business requires forest products, and which are

well established, sometimes undertake to manage their own forests. Paper-mills have in some cases planned their own forests to take care of their need of spruce. Railroads are in some cases growing their own ties. The United States Forest Service has under its control large forest areas at the present time. These are being admirably managed.

For the individual there is here also a possible source of profit. It has been found that farmers living in places remote from a natural supply of Christmas trees—in Ohio and Indiana, for example—can realize as much as $300 an acre annually by growing suitable trees. The field is plowed as for any other crop, and seedlings are planted. It requires about five years for the crop to be suitable for Christmas trade. The profit of $300 is figured, however, from the time of planting. The first crop is only a thinning of the trees, which is necessary to permit the proper growth of those remaining. The area can be thinned every year up to about twenty-five years, when the crop will be matured. As the trees grow larger, they are, of course, sold for lumber.

Forest conservation does not mean leaving the forest alone and taking nothing out of it. It means scientific management. The stand of trees must be thinned periodically. In the beginning a thick stand is desirable, as it forces the trees

to grow higher to reach the sun's rays. The weaker ones, which fall behind, are then eliminated in order that they may not rob the stronger, healthier trees of needed food and light. In this way there is afforded to the forester a constant income, once the forest is established.

Transplanting Birds

In the single year 1928 more than half a million birds were imported into the United States. The total number was 682,308. Since 358,449 were canaries and 56,307 were parrots, the number of imported birds intended to be freed is reduced by this amount, as canaries and parrots are imported mainly as cage or exhibition birds. It still leaves a large number of birds which were set free, however. Of these, quail constitute a large proportion, 84,915 having been imported. Next in number stand pheasants, ruffed grouse, and ducks. When one realizes that in addition to these importations there were also going on experiments in transplanting birds within the boundaries of the country itself, the magnitude of the undertaking can be realized.

Despite the time and money thus spent, however, the factors which determine the success or failure of such experiments are not known. There are those who do not favor attempts to bring in any new birds because of the possi-

bility of bringing with them new bird diseases or bird pests. On the other hand, there are those who, John C. Phillips says, "would bring in anything from a button quail to an ostrich without any regard for the general suitability of the species." Mr. Phillips has made a comprehensive study of this problem.

In general, transplanted birds behave in four rather distinct ways. They may stay around a short time without nesting and then suddenly disappear. This often happens in what would appear to be a particularly favorable environment. Where they go is never determined. California quail brought into the Eastern States behave in this way, as do also some European song-birds.

The next class is one of partial success. The birds may nest the first season, but in succeeding years fail to do so. The original birds will be found in the neighborhood for a number of years. This behavior is characteristic of European partridges released in Massachusetts and Connecticut.

The third class attain a local success. They may nest and increase locally for a number of years, but they do not spread. Eventually they are likely to disappear suddenly and completely, perhaps as the result of an especially hard winter.

The fourth class is that of complete success.

The birds are for a period free from natural enemies and diseases common to the place of origin. As a result they increase to the proportions of a pest. Eventually, however, they come under control. This was the case with the English sparrow. Released in America by the Brooklyn Institute in 1850, these birds reached their height about the beginning of the century. They have now been brought under control. The history of our present starling pest is somewhat the same story. Many attempts were made to introduce this bird, beginning as far back as 1872, but all of them were unsuccessful. The present starlings, found in almost every part of the country, are all descended from fifty pairs that were released in Central Park, New York City, in 1890 and 1891.

In the case of migrating birds the difficulty of transplanting is much greater than otherwise. Usually when they go south in the fall it is never to return. This has been the case with Egyptian quail. Many thousands of these were released in this country between the years 1870 and 1880. Mallard ducks, many of which have been released on Long Island by sporting clubs, likewise never return. They appear to go north up the Mississippi River along with others of their kind on their way to Canada.

A very thorough study of this whole problem is now in progress by the Biological Survey.

Complete account of every bird entering the country by importation is kept, and in addition an extensive program of bird banding is being carried out with the aid of experienced amateurs in all parts of the country. Many thousands of birds are being banded annually and their movements determined by subsequent trapping. Since the birds are of course uninjured, they are freed again, later to be again reported by a similar means. Some have already been reported several times in various localities. It is thought that in this way the facts about bird migrations, the possibilities of transplanting, and so on, will be definitely established.

Farm Waste

The farmer has become a scientist, and therein lies his present difficulty. During the period 1900 to 1920 the falling off of farm products in this country led to the establishment of all kinds of agencies to educate the farmer in scientific methods of agriculture. The agricultural press, farm organizations, agricultural colleges, extension service and experiment stations, State and Federal agricultural departments, have all joined in the spread of such knowledge. They have done their job well. The census of 1925 showed, for the first time in the history of the nation, a decrease in acreage under cultivation. There was a decrease of 13,000,000 acres over

that harvested in the period 1919 to 1924. The acreage is still rapidly decreasing. In spite of this, larger crops are produced than formerly.

"Agricultural production as a whole," says Mr. O. E. Baker, of the United States Department of Agriculture, "was 14 per cent. greater in the period 1922-26 than in the period 1917-21, whereas population increased less than 9 per cent. in the same periods; in other words, the increase of agricultural production was more than 50 per cent. greater than the increase of population.

"Moreover," continues Mr. Baker, "the acreage in pasture on farms has decreased (but not total pasture), and the number of horses and cattle and hogs has decreased notably; indeed, beef cattle are less numerous than at any time during the last forty years, and there are about the same number of hogs in the United States as forty years ago. Furthermore, the number of farms has decreased since the World War years, the farm population and the number of farm laborers has decreased even more, and the average acre-yield of crops has increased only slightly."

Fewer farms, fewer acres, fewer animals, yet more grain, more meat, more dairy products are available. How can this be?

To begin with, the advent of the farm tractor has filled a double rôle. It has cut down greatly

the amount of labor necessary on the farm, and it has relieved those acres formerly needed to grow feed for horses used on the farm. The new combine, now coming into use, will further cut down the necessary farm help, and leave an oversupply of farm labor for some time to come. Horses and mules are being raised in only about half the numbers necessary to replace those which die.

Now, how do we get more milk from fewer cows, more meat from fewer animals? A century ago our best cows probably gave not over 2,000 pounds of milk annually. Our best dairies to-day average 5,000 pounds per cow. Some cows even reach the 10,000-pound mark. A 5,000-pound cow eats much more than half the food required for a 10,000-pound cow; probably two-thirds as much. It requires just as much care. The change is the result of scientific breeding and feeding. More meat is available with fewer cattle because they are killed younger. The fastest growth is in early age. The proportion of calves slaughtered as compared to the number of older animals is rapidly increasing.

Other causes of the change are such things as better insect control, the greater and more intelligent use of fertilizers, and the introduction of fertilizers which are scientifically correct for the particular land under cultivation. Then, too, there have been introduced new and hardier

plant varieties—varieties immune to various diseases, and varieties which mature quicker. Our changing food habits are also a factor in this farm problem.

This all means that many of our present farmers will have to find new occupations or that a new source of income will have to be provided in some fashion. Scientists are working on the question. The most likely solution at present seems to be in the utilization of farm waste as by-products. Insulation board is now being made from wheat straw, rayon is being made from corn stalks, and many other marvelous things are taking place which can best be described in a review of chemistry. At present all these promising developments are in the experimental stage. They hardly offer more to the farmer for his waste than he can realize by plowing it under as fertilizer. They offer an interesting future for the farm, however; the farmer may yet find himself a dealer in raw chemicals.

Mulching Crops with Paper

For many years it has been the custom in the Hawaiian sugar plantations to leave the crop refuse, such as leaves, tops, etc., between the rows. This mulch served the double duty of conserving the soil moisture and keeping down the weed growth. Because of the temporary nature of such mulch, it occurred to Mr. C. F. Eckart,

manager of one of the plantations, to place between the rows a cheap grade of asphalt paper. This was so successful that he later completely covered the field. The stiff shoots of the sugar-cane would penetrate the paper, while the weed would not. This was later extended to the pine-apple crop, and now it is estimated that 90 per cent. of this crop is so mulched. Holes are made in the paper, so that the pineapples can come through.

Because of the success met with in Hawaii by mulching with paper, many experiments have been carried out in the United States on various vegetables, particularly by Mr. L. H. Flint. In general he has found the production increase to range from about 30 to 500 or 600 per cent.

The reasons for this increase in crop production are many. The paper mulch has the property of keeping the top few inches of soil much more moist. It has been found that twelve days after a rain the mulched soil may contain as much as 20 per cent. more moisture than the unmulched in the same neighborhood. Where weeds were allowed to grow, it would doubtless be much greater; for in dry times the chief damage which weeds do is to dissipate the moisture in the soil through their leaves. Where the plants are allowed to grow through perforations, even a light rain, ordinarily of little benefit, is of great value. What water there is runs through

the holes directly upon the plants, where it is needed.

It has also been found that the temperature under the mulch is on the average about 10 degrees higher than in the open. This produces a semi-tropical condition which allows plants to be grown many miles north of their usual habitat. It also causes plants to mature weeks ahead of their usual time. This not only brings better prices, but may frequently allow two crops where otherwise only one would be possible. It is also found that the increased temperature causes nitrate-forming bacteria to work faster. Plants taken from mulched soil are higher than others in nitrates.

The cost of labor is obviously lessened. There is neither hoeing nor weeding to be done. It is also found that plowing is unnecessary. Plowing is in any case largely for the purpose of keeping down weeds, and in the mulch experiments it is so far found that the crop does not suffer from its lack.

At the present time there are coming on the market many papers especially prepared for this purpose. Such papers may be left in place for as long as five years. Some have perforations which will permit moisture to pass through and yet check weed growth. Almost any grade of asphalt paper will give most of the benefits of these special mulching papers; much work, how-

ever, is now being done to develop a lasting cheap paper for this purpose.

When the plants are protected from weed competition, they develop, as a rule, to a larger size. They are also protected from many plant diseases and insects. In fact, the mulch gives many of the benefits of a greenhouse without the large cost. It will, of course, never replace the greenhouse, which offers all these advantages in much greater measure and supplies a year-round occupation to its operator.

Farm Engineering

Farm engineering is a new name for intelligent farm planning. Too often a farmer works too much with his back and too little with his head. He finds himself just so far behind that he never has time to stop to think his way out of the muddle. It is farmers of this kind who are falling by the wayside in the present race.

There are many engineering factors in producing, harvesting, and marketing farm products. Let us consider a few of them. Shall the farmer clear more of his land for crops? To do so might cost him $150 to $200 per acre, and if he undertakes it he figures that he has permanently added this value to his farm. Perhaps he has not the proper facilities to care for the additional land. It may result in poor management for the rest of his acres. Perhaps for $40 an acre he might

have drained some land now in operation, or he might have irrigated some land, and so increased its efficiency from 10 or 20 per cent. to 100 per cent. without laying up unnecessary work for himself in the future. Drainage and irrigation are as a rule given less thought than increased acreage. The wise farmer to-day does not buy acreage. He buys fertile land with an eye to the cost of operation.

Frequently the farm road may deserve attention. The farmer may find that the number of loads to harvest a crop may be greatly decreased by improving the road to his fields. This may be done with easily available stone. It may be done by easing the grades.

It is not uncommon for the load that a farmer can draw to market to be limited by the road to his own gateway. From there on he finds easy grades on hard-surfaced roads. Yet year after year he takes undersized loads to town. A little work in an off season would alleviate this condition for all time. Proper engineering might even suggest a hard-surfaced road in his own yard. The movement of the product is one of the first considerations in locating a factory; it should be considered also on the farm.

Then, too, there is an engineering problem in the location and management of the water supply. The location is often inconvenient. The proper storage and care of his farm machinery

may save him hundreds of dollars a year. The same is true of his harvested crops.

Where a farm employs several laborers, a division of labor is often desirable, giving the men charge of those things in which they evince a particular interest. This is but following out the plan of the management of any business. The successful farmer must show executive ability.

The farmer cannot be expected to know everything, but he should know where to find out those things which will help him. If he lacks engineering knowledge he will probably save himself many dollars in costly errors by calling in an engineer. Those who specialize in this kind of engineering are now available. It offers a new vocation for the engineer, which may be expected to become popular with the farm boy, suitably gifted, who finds that modern methods have left no place for him on the farm, or who prefers work of this type. The surveyor's instrument is already taking the place of sighting over posts.

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